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PARASITOLOGY

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PARASITOLOGY

EDITED BY

GEORGE H. F. NUTTALL, F.R.S.
Quick Professor of Biology in the University of Cambridge

AND

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Reader in Zoology in the University of Cambridge

ASSISTED BY

EDWARD HINDLE, PH.D.

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19 JUL 1913

BRITISH MUSEUM NATURAL HISTORY Z D

ON FOUR NEW SPECIES AND TWO NEW VARIETIES OF THE IXODID GENUS *HAEMAPHYSALIS.*

BY CECIL WARBURTON, M.A., F.Z.S.,
Demonstrator to the Quick Professor.

(From the Quick Laboratory, University of Cambridge.)

(With 8 Text-figures.)

THE following new species and varieties are dealt with in this paper:

Haemaphysalis aborensis n. sp. (♀) Yambung, India (Indian Mus. $\frac{1251}{17}$).
,, *howletti* n. sp. (♂ ♀) Rawalpindi, India (N. 1979).
,, *aciculifer* n. sp. (♂ ♀) Uganda (Ent. Res. Com. 463 *a*).
,, *kinneari* n. sp. (♀) Kanara, India (N. 1997).
,, *cornigera* var. *anomala* n. var. (♂) India (Indian Mus. $\frac{1524}{17}$ *a*).
,, *inermis* var. *aponommoides* n. var. (♀) Belgachia, Calcutta, India (N. 1566).

Introduction.

The examination of a vast number of ticks, collected in late years from various hosts in many parts of the world, has resulted in the addition of several new species to the genus *Haemaphysalis.* Though only 13 of the species admitted by Neumann in his "Révision" (Pt. II, 1897) still stand, the number of recognised good species now reaches 43.

Just as *Rhipicephalus* is proper to Africa, so *Haemaphysalis* is essentially Asiatic, and the Indian region has furnished most of the newly discovered forms. One of the new species described below is African, the remainder being additions to the Indian fauna.

The difficulties presented by the genus *Haemaphysalis* are chiefly due to the fact that its principal characteristics are mainly negative. In the absence of ornamentation, of eyes, of anal plates in the male, and of lateral grooves in the female, the points available for specific diagnosis are much reduced in number. Nevertheless, there is no lack of clearly defined forms, and it is noteworthy that, owing to the slight sexual dimorphism, there is less than the usual danger—certainly vastly less than in *Rhipicephalus*—in establishing a new species for one sex only. It is unfortunate that certain species fail to conform to the general type in a point which is, so far as general facies is concerned, the most striking characteristic of the genus as a whole—namely, in the form of the palps. These are, typically, short and conical, the second article projecting laterally. In certain cases, however, they are distinctly long, and the lateral salience may be much reduced or even entirely absent. An extreme example is the new variety of *H. inermis* (var. *aponommoides*) described below. It seems impossible to remove such aberrant forms to a new genus, for there is no clear line of demarcation.

We propose the following diagnosis for the genus *Haemaphysalis*: Inornate, eyeless ticks, of comparatively small size and generally rather feebly chitinised; sexual dimorphism slight, the ♂ being destitute of anal plates. Capitulum with basis sub-rectangular, and with palps normally short and conical, broadest near the posterior end of article 2. Female scutum without lateral groove; trochanter I with blade-like dorsal retrograde process; spiracle sub-circular or short-comma-shaped; coxa I never bifid.

My thanks are due to Mr N. Cunliffe, B.A., for his careful drawing of the figures given below, and for other assistance in the preparation of this paper.

Haemaphysalis aborensis n. sp.

Male: Unknown.

Female: (Unfed, and perhaps not fully chitinised).

Scutum: Broader than long (1·5 × 1·8 mm.), broad-oval, pale yellow in the specimen; punctations numerous and fairly large on the lateral areas and on the posterior portion, but inconspicuous in the median field; cervical grooves visible to the posterior border.

Capitulum: Basis much broader than long, cornua short and blunt; porose areas ill-defined, ovate, the interval greater than their diameter; palps with very slight and obtuse lateral salience on article 2, of which the internal border is nearly straight, and much longer than the external border; the dorsal surface of articles 2 and 3 smooth, rounded, and destitute of spines; a short, blunt spur under article 3; hypostome spatulate, well-covered on its anterior $\frac{2}{3}$ by sub-equal teeth, the dentition 4 | 4.

Venter: Spiracle large, transverse-oval, with slight, blunt dorsal projection; anal groove nearly semicircular, with hardly any visible caudal prolongation.

Legs: Very long and strong, especially the first pair, which, in the specimen, are brown and fairly well chitinised, while the others are pale yellow; coxal armature very slight, coxa I having a short, blunt internal spur, while coxae II–IV have a slight protuberance in the middle of the posterior border; tarsus IV long and tapering; claws long, pad rather short.

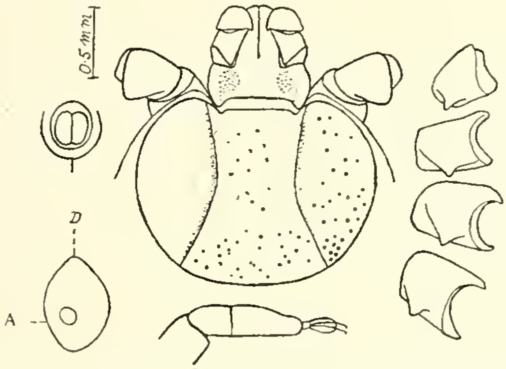

Fig. 1. *H. aborensis* ♀, capitulum and scutum, anus, spiracle, tarsus IV and coxae. (N. Cunliffe, del.)

Described from a single specimen taken in grass (by sweeping) by S. W. Kemp (Abor Expedition) at Yambung, at an elevation of 1100 ft. Apparently a very large species.

[Type in the Indian Museum: No. $\frac{1251}{17}$.]

Haemaphysalis howletti n. sp.

Male: Of the general appearance of *H. campanulata* Warb., 1908, from which, however, it differs in the following respects:

Size smaller.

Scutum more densely and deeply punctate, and less rounded at the posterior end.

Spiracle sub-rectangular, with very slight, blunt dorsal process.

Dentition at least 5 | 5 (perhaps 6 | 6) very small, sharp teeth.

Tarsus IV longer and more tapering.

Female: *Scutum:* Much longer than broad (1·1 × 0·7 mm.), long-oval, of nearly uniform width throughout, strongly and deeply punctate, the punctations more or less confluent on the lateral fields; cervical grooves beginning as pits at some distance from the anterior border, and continuing as shallow depressions for about $\frac{2}{3}$ of the scutal length.

Capitulum: Much like that of *H. campanulata*; porose areas oval and far apart, with a median depression between them; dentition 5 | 5, teeth very small and confined to the distal part of the hypostome.

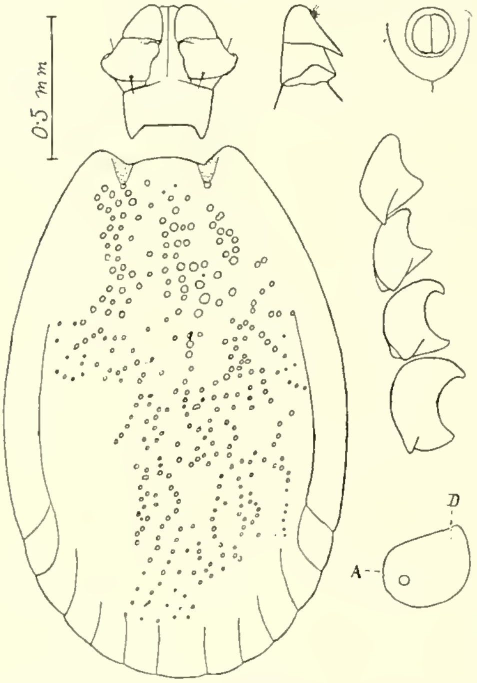

Fig. 2.

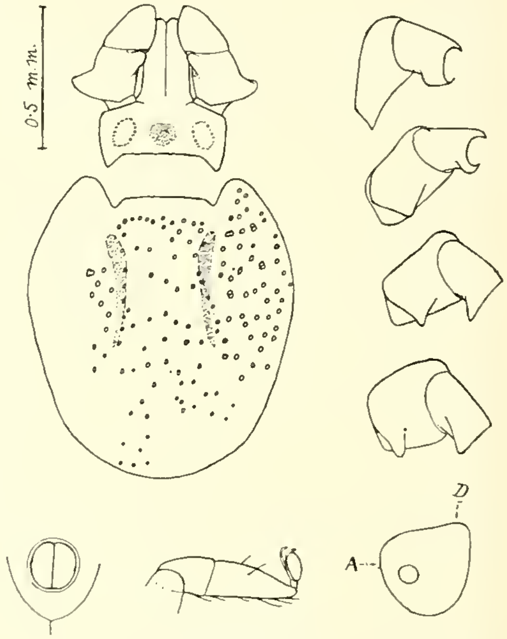

Fig. 3.

Fig. 2. *H. howletti* ♂, capitulum, scutum, profile of capitulum, anus, coxae and spiracle. (N. Cunliffe, del.)

Fig. 3. *H. howletti* ♀, capitulum, scutum, coxae and trochanters, anus, tarsus IV and spiracle. (N. Cunliffe, del.)

Dorsum closely and deeply punctate all over; tarsi tapering.

Described from 1 ♂ and 1 ♀ taken by F. M. Howlett from a hill pony at Rawalpindi, India (no date).

This species is very near *H. campanulata*. It is, however, smaller and much more punctate, and has quite a different hypostome, that of *H. campanulata* being well-covered with 4 | 4 large teeth. The different shape of the female scutum, and the tapering tarsi in both sexes, will also serve to distinguish it from that species.

The types are in the Quick Laboratory, Cambridge (N. 1979).

Haemaphysalis aciculifer n. sp.

Male : About 2 × 1·2 mm. (capitulum included).

Scutum : Oval, widest in the middle, glossy, with very fine, shallow, unequal punctations ; cervical grooves short, fairly distinct ; lateral grooves distinct, rather short, concave internally, including one festoon ; festoons fairly long and rather broad.

Capitulum : Base rectangular, with strong cornua ; palps short ; article 2 short and only slightly salient laterally, prominent, but without spine ventrally ; article 3 slightly salient laterally, breaking the external contour, without dorsal spine but slightly protuberant where a spine might be expected, recurved at its postero-internal margin. The whole internal contour of the palp is characteristic (see Fig. 4). Hypostome short, dentition 4 | 4, teeth small.

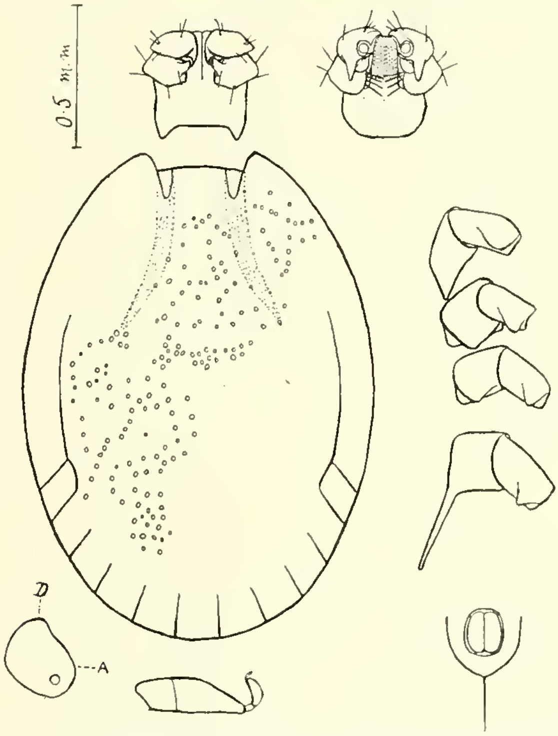

Fig. 4. *H. aciculifer* ♂, capitulum (dorsal and ventral aspects), scutum, coxae and trochanters, spiracle, tarsus IV and anus. (N. Cunliffe, del.)

Venter : Spiracle rather broad, with very slight, blunt dorsal process ; anal groove slightly ogival.

Legs : Coxa I with strong internal spur and a slight hint of an external spur ; coxae II and III with slight protuberance in the middle of the posterior border ; coxa IV with long, needle-like, internal spine (hence *aciculifer*) longer than the article itself, and narrow from its origin; slight progressively diminishing trochantal spurs; tarsus IV tapering rather abruptly; pads rather long.

Female: *Scutum*: Cordiform, slightly longer than broad (0·8 × 0·7 mm.), widest $\frac{1}{3}$ from anterior end; punctations (in the single specimen, which is young and apparently not fully chitinised) small and inconspicuous; cervical grooves well marked, slightly converging, visible for about $\frac{2}{3}$ of scutum; emargination fairly deep.

Capitulum: Basis much broader than long, cornua strong; porose areas oval and far apart; palps as in the ♂, especially as regards their internal contour, but the dorsal protuberance on article 3 is more marked and pointed, almost amounting to a spine; hypostome 4|4.

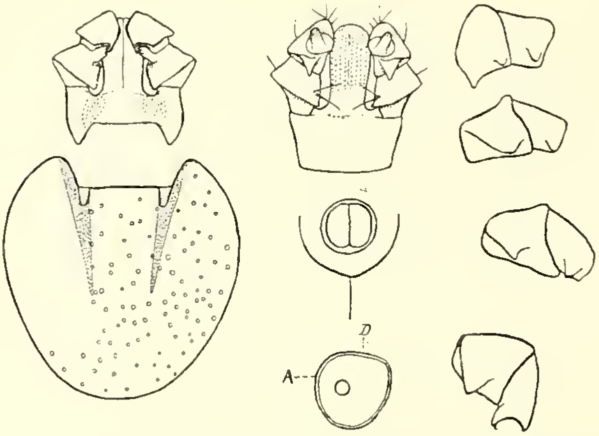

Fig. 5. *H. aciculifer* ♀, capitulum (dorsal and ventral aspects), scutum, anus, spiracle, coxae and trochanters. (N. Cunliffe, del.)

Venter: Spiracle sub-circular; anal groove slightly ogival.

Legs: Coxa I with fairly sharp internal spur; coxae II–IV with slight protuberance near the middle of the posterior border, strongest on coxa IV; tarsi as in the ♂.

Described from 1 ♂ and 1 ♀ taken, in company with *Rhipicephalus appendiculatus*, from *Cobus thomasi* (an antelope), on the N.E. shore of Lake Edward, Uganda, x. 1911, by S. A. Neave.

Types in Entomol. Research Committee's Collection, No. 463 *a*.

The entire absence of anything in the ♀ corresponding to the long, needle-like spine on coxa IV of the ♂ caused some hesitation in attributing these two specimens to the same species, but they agree very completely in general structure, especially in the conformation of the palps. In those species in which the ♂ has a long spine on coxa IV, this is always much reduced in the ♀.

Haemaphysalis kinneari n. sp.

Male : Unknown.

Female : *Scutum :* Sub-circular, slightly broader than long (0·8 × 0·9 mm.), with numerous medium or rather large punctations, most numerous on the lateral fields; cervical grooves, beginning as shallow depressions, deepening into oval pits at some distance from the anterior border, then broad and shallow to within a short distance of the postero-lateral borders.

Capitulum : Basis twice as broad as long, rectangular, with blunt cornua; porose areas apparently nearly circular, but ill-defined and not easily distinguished; palps long and, in general facies, much like those of *H. montgomeryi*, Nuttall, 1912, having the lateral salience slight and very obtuse; instead, however, of being smoothly rounded as in that species, their dorsal surface presents corrugations, article 3 has an irregular posterior border, and the internal contour of article 2 presents a strong rounded protuberance anteriorly; moreover, article 2 bears no ventral retrograde spur, though one is present under article 3; dentition 4 | 4.

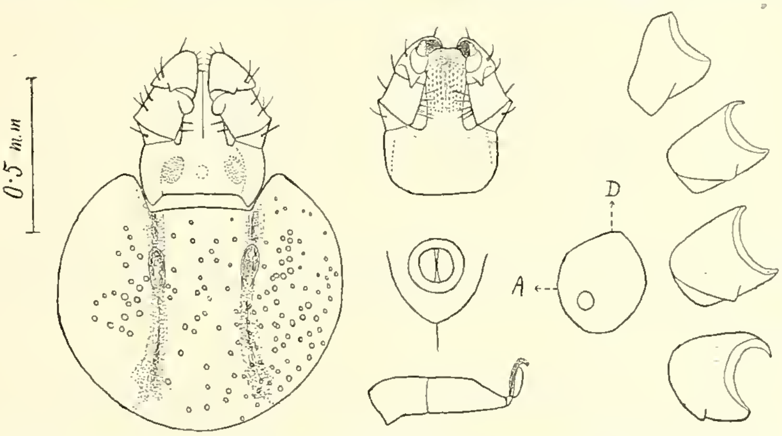

Fig. 6. *H. kinneari* ♀, capitulum and scutum, ventral aspect of capitulum, anus, tarsus IV, spiracle and coxae. (N. Cunliffe, del.)

Venter : Spiracle rather large, oval, with blunt dorsal process; anal groove very slightly ogival.

Legs : Coxae with very slight armature of the normal type; tarsus IV rather long (especially the proximal pseud-articulation), somewhat tapering; no trochantal spurs.

A large species, recalling in general appearance *H. montgomeryi*, but easily distinguished from that species by the rounded scutum; the absence of a spur under article 2 of the palp; the very slight coxal armature; and the absence of trochantal spurs.

Described from a single ♀ taken from a tiger at Kadra, Kanara, India (Bombay Nat. Hist. Mammal Survey), by N. B. Kinnear (after whom it is named), in Nov., 1910, in company with some ill-characterised *H. bispinosa*, and with *Amblyomma prolongatum*.

Type in the Quick Laboratory, Cambridge (N. 1997).

Haemaphysalis cornigera var. **anomala** n. var.

Male: Closely resembles the type except in the following respects: *The 3rd article of the palps not projecting laterally* (hence *anomala*).

Basis capituli somewhat narrower compared with its length; spiracle more pointed dorso-laterally.

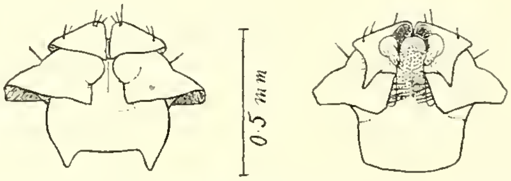

Fig. 7. *H. cornigera* var. *anomala*, dorsal and ventral aspects of capitulum. (N. Cunliffe, del.)

Female: Unknown.

The most remarkable characteristics of *H. cornigera*—the presence of two divergent spines under article 3 of the palps, and of a double spine on coxa IV—are repeated in this variety.

Described from a single ♂ taken from a wolf, four miles west of Koderma Station, Chota Nagpur, India, by Major O. A. Smith, VIII. 1912. In its company were specimens of *H. bispinosa* var. *intermedia*, *H. leachi*, and *Rhipicephalus haemaphysaloides*.

Type in the Indian Museum, $\frac{1524}{17}$ *a*.

Haemaphysalis inermis var. **aponommoides** n. var.

Male: Unknown.

Female. *Scutum*: Broader than long (1 × 1·4 mm.), broadest at the anterior $\frac{1}{3}$, and much more narrowed posteriorly than in the type; glossy, but with numerous discrete, medium-sized punctations; cervical grooves broad sub-parallel tracts without any initial pits; emargination slight.

Capitulum: Even more *Aponomma*-like than in the type; basis bluntly salient at the sides, almost destitute of cornua; porose areas large, sub-circular, bounded externally and anteriorly by sub-rectilinear ridges, the interval about equal to their diameter; palps long and narrow, their outer border straight and not convex as in the type; article 1 well visible; articles 2 and 3 not distinctly separated, article 2 corrugated dorsally, and without any trace of lateral salience; hypostome spatulate, dentition 3 | 3.

Venter: Spiracle ovate, the narrow end postero-dorsal; anal groove semicircular.

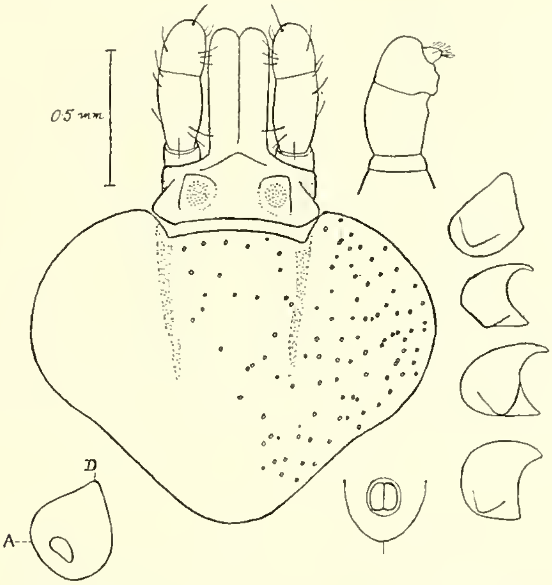

Fig. 8. *H. inermis* var. *aponommoides* ♀, capitulum and scutum, profile of palp, coxae, spiracle and anus. (N. Cunliffe, del.)

Legs: As in the type; coxa I without definite spine, but with its internal end truncated and the corners slightly protuberant; coxae II–IV with a slight protuberance in the middle of the posterior border; tarsus IV rather long and tapering (as in *H. howletti* ♀, see Fig. 3).

Described from numerous ♀s taken by Colonel F. Raymond, F.R.C.V.S., from a Himalayan Zebu at Belgachia, Calcutta, iii. 1912, in company with *Boophilus australis.*

Types in the Quick Laboratory, Cambridge (N. 1566).

H. inermis, Birula, 1895, has always been considered the most aberrant form of *Haemaphysalis,* and its attribution to that genus would be extremely doubtful were it not for such intermediate forms as

H. warburtoni, Nuttall, 1912. The present variety still further departs from the normal *Haemaphysalis* type, and still more closely approaches *Aponomma*. The genera *Haemaphysalis* and *Aponomma* have normally little in common, except the negative characteristics of the absence of eyes and anal plates, and we should not have expected any question to arise as to which of them a newly discovered form belonged. Yet a grave question does arise in the present case, and though we judge the tick here described to be a *Haemaphysalis*, its resemblances to an *Aponomma* are not merely superficial. It possesses one *Haemaphysalis* characteristic never found in *Aponomma*—the blade-like dorsal retrograde spur on trochanter 1. Moreover, it is found on a mammal, whereas *Aponomma* is essentially parasitic on reptiles. The long palps need not trouble us much, as we know of several undoubted species of *Haemaphysalis* almost equally aberrant in this respect; and, though the palps are long and very *Aponomma*-like when viewed dorsally, they do not recall that genus when viewed in profile (see Fig. 8). The *Aponomma*-like shape of the scutum, also, is of little importance, for there is a great range of scutal design in *Haemaphysalis*. It must be admitted, however, that not only the dentition (3 | 3) but the whole appearance of the hypostome is more like that found in *Aponomma* than *Haemaphysalis*, and that coxa I, though not distinctly bifid, displays a tendency in that direction.

NOTES ON TICKS. III.

ON FOUR NEW SPECIES OF *IXODES*.

By G. H. F. NUTTALL, F.R.S.
(ILLUSTRATED BY N. CUNCLIFFE, B.A.).

(From the Quick Laboratory, University of Cambridge.)

(With 4 Text-figures.)

THE new species herein described are of interest, although we can only deal with females, as is so frequently the case with this genus. One species (*I. kempi*), allied to the North American *I. angustus*, comes from a hitherto unexplored region on the north-east frontier of India, having been collected by the Abor Expedition. Two species (*I. daveyi* and *I. oldi*) are from Africa, and offer a peculiarity of structure in that they possess anal grooves having the form of a horse-shoe, an appearance only hitherto observed in three other species of *Ixodes*, all of which are African. The fourth species (*I. ricinoides*) is from China, and is allied to our *I. ricinus*:

Ixodes kempi ♀, from Kobo, Abor Country. (Indian Mus., Calcutta, 1247/17.)
,, *daveyi* ♀, from Rusvenzori, Uganda. (Imperial Bur. of Ent., 470.)
,, *oldi* ♀, from Komatendu, Sierra Leone. (Imperial Bur. of Ent., 604.)
,, *ricinoides* ♀, from Wen-chwan-hsien, China. (Our Collection, 1401, 1402.)

Ixodes kempi n. sp.[1]

(Fig. 1.)

Male: Unknown.

Female: Hard parts blackish-brown (as in *I. ricinus*). (*Dorsal aspect.*) *Scutum* with pointed scapular angles, emarginate, longer than broad, varying between 1·5 × 1·0 and 1·2 × 0·9 mm. in size[1], appearing longer in proportion to the width than is shown in the measurements, broadest at about the anterior third, where there are more or less distinct lateral angles[2]; cervical grooves shallow, converging and then diverging widely, not attaining the posterior border; lateral grooves marked by a more or less salient ridge attaining the postero-lateral border; many coarse, uniformly distributed punctations, especially between the cervical grooves posteriorly; no hairs. *Capitulum*: Base somewhat triangular dorsally, appearing longer than broad, dorsal ridge straight, with minute rounded cornua; porose areas large, of irregular shape, situate near the posterior border, depressed, sharply defined, the interval less than their diameter; a straight lateral ridge runs forwards along the sides of the basis capituli. Palps long, article 3 shorter than 2, both articles being hollowed on the internal dorsal surface; article 3 rather pointed in front; article 1 large and protruding. (*Ventral aspect.*)

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[1] Named after the collector.

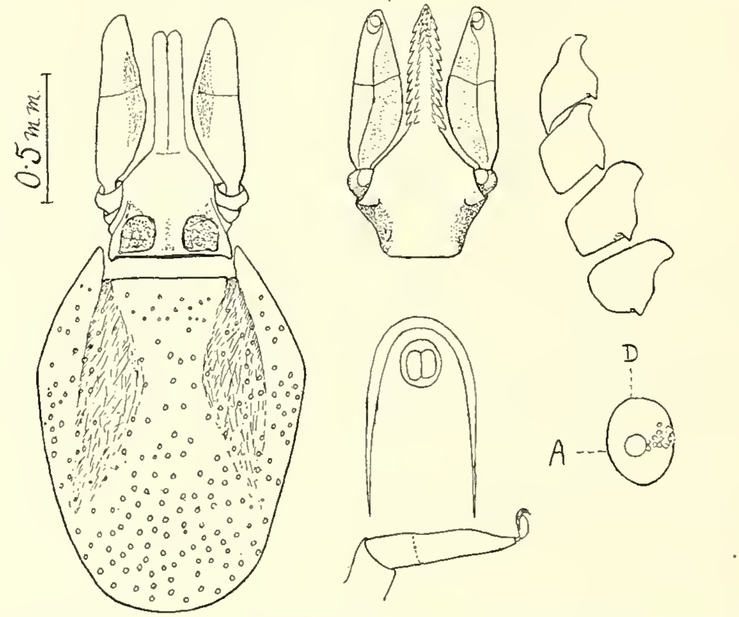

Fig. 1. *Ixodes kempi* n. sp. ♀. Capitulum and scutum; capitulum in ventral aspect, coxae I–IV, anal groove, spiracle and tarsus 4. (N. Cunliffe, del.)

---

[1] The largest partly gorged specimen measures 7·1 × 5·3 mm. The scutums of the 8 ♀s measured as follows:

No. 1.	1·5 × 1 mm.	No. 5.	1·3 × 1 mm.
No. 2.	1·3 × 1 ,,	No. 6.	1·2 × 1 ,,
No. 3.	1·3 × 1 ,,	No. 7.	1·2 × 0·9 mm.
No. 4.	1·3 × 1 ,,	No. 8.	1·2 × 0·9 ,,

[2] In one specimen the sides are sub-parallel, the lateral angles being absent.

Hypostome sharply pointed, dentition 2|2, with 11 stout teeth along the outer file. Auriculae slightly marked, edged; ventral base narrows slightly behind, posterior margin almost straight; the first palpal article with backwardly-protruding flange. *Venter*: Vulva between coxae IV; anal groove rounded in front, short, not attaining the posterior border and converging somewhat behind in slightly fed females, but divergent in more replete specimens. Spiracles transversely oval; macula near centre. *Legs*: Coxa I with sharp internal and short pointed external spur; coxae II–IV with short external spur; coxae II–III angular internally. Tarsi tapering; pad almost as long as the claws.

Described from eight partly gorged ♀s, found on *Sciurus erythraceus intermedius*, at Kobo (400 feet elevation), India, Abor Expedition, by S. W. Kemp, 29. III. 1912. (Indian Museum, Calcutta, No. 1247/17.) This species is allied to *I. angustus*, but differs therefrom as follows: scutum coarsely punctate, hairless; auriculae present; anal grooves short and rounded in front of anus; coxa IV with external spur.

Ixodes daveyi n. sp.[1]

(Fig. 2.)

Male: Unknown.

Female: Hard parts chestnut brown. (*Dorsal aspect.*) *Scutum* with very pointed scapular angles, emarginate, a third longer than broad, 1·6 × 1 mm., with rounded lateral angles, the sides narrowing posteriorly to where the cervical grooves end; posterior margin rounded; cervical grooves deep, diverging widely behind and attaining the postero-lateral margins; no lateral grooves; numerous fine punctations obscured by slight rugosities; lateral fields rugose; no hairs. *Capitulum*: Base having roughly the form of an equilateral triangle; dorsal ridge slightly concave, cornua slightly marked, sides converging anteriorly and forming a ridge running to the inner side of the palpal articulation; porose areas very large, slightly depressed, their broadest parts separated by an interval equal to about half their median antero-posterior diameter. Palps long, somewhat pointed distally, articles 2–3 with concave external contour, article 2 bulging out basally before becoming constricted at the joint; article 1 small. (*Ventral aspect.*) Hypostome long and tapering gradually to a fine point bearing fine denticles, 2|2, with 11 distinct teeth on the outer files and a broad median unarmed surface.

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[1] Named after Dr J. B. Davey, late of the Sleeping Sickness Commission, who has collected much valuable material and aided us in our investigations.

Auriculae angular, trenchant, the basis capituli being constricted behind them and then broadening; posterior ventral margin of base almost straight; palpal article 1 with slight ventral protrusion. *Venter*: Vulva between coxae IV; anal groove horse-shoe-shaped, converging behind. Spiracles ovoid, with macula almost central. *Legs*: Coxa I with sharp internal and external spurs; coxae II–IV with sharp external spur growing progressively smaller from II to IV. Trochanters II and III with sharp distal spurs, a slight protrusion on coxae I and IV in the same situation. Tarsi tapering, slightly shorter than the claws.

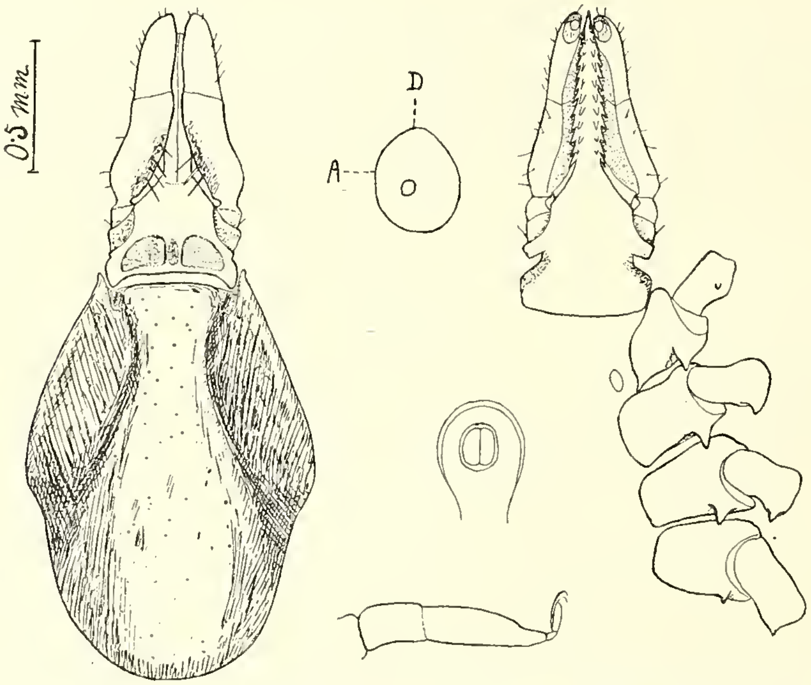

Fig. 2. *Ixodes daveyi* n. sp. ♀. Capitulum and scutum; capitulum in ventral aspect with coxae and trochanters, spiracle, anal groove and tarsus 4. (N. Cunliffe, del.)

Described from a single slightly fed ♀ found on *Gallirex johnstoni* Sharpe, a bird, on the northern ridge of Rusvenzori (6000–8500 feet elevation), Uganda, by S. A. Neave, XI. 1911. (Imperial Bureau of Entomology, No. 470.)

This species resembles *I. lunatus, schillingsi, pilosus* and *oldi* in the possession of a horse-shoe-shaped anal groove. These species differ from *I. daveyi*, however, in the following main points:

I. pilosus has coxae II–III unarmed, and the scutum shows a lateral groove; *I. lunatus* has an oval scutum bearing lateral grooves and not having pointed scapulae; *I. schillingsi* has a deeply punctate scutum without pointed scapulae, coxae II–III unarmed and trenchant: *I. oldi* has a short basis capituli, short palps, oval scutum with lateral ridges, coxae II–IV unarmed.

Ixodes oldi n. sp.[1]

(Fig. 3.)

Male: Unknown.

Female: Hard parts chestnut coloured. (*Dorsal aspect.*) *Scutum* with rounded scapular angles, but slightly emarginate, nearly as broad as long, varying between 1 × 0·8 and 0·9 × 0·8 mm.[2], but appearing longer in proportion to the width; broadest either midway or at about the anterior third (varies), rounded laterally; cervical grooves shallow, diverging posteriorly and not attaining the posterior border; lateral grooves marked by a salient ridge which is more or less distinct, and, when marked, attaining the postero-lateral border; many moderately coarse punctations uniformly distributed, especially between the cervical grooves posteriorly; no hairs. *Capitulum*: Base shorter than broad,

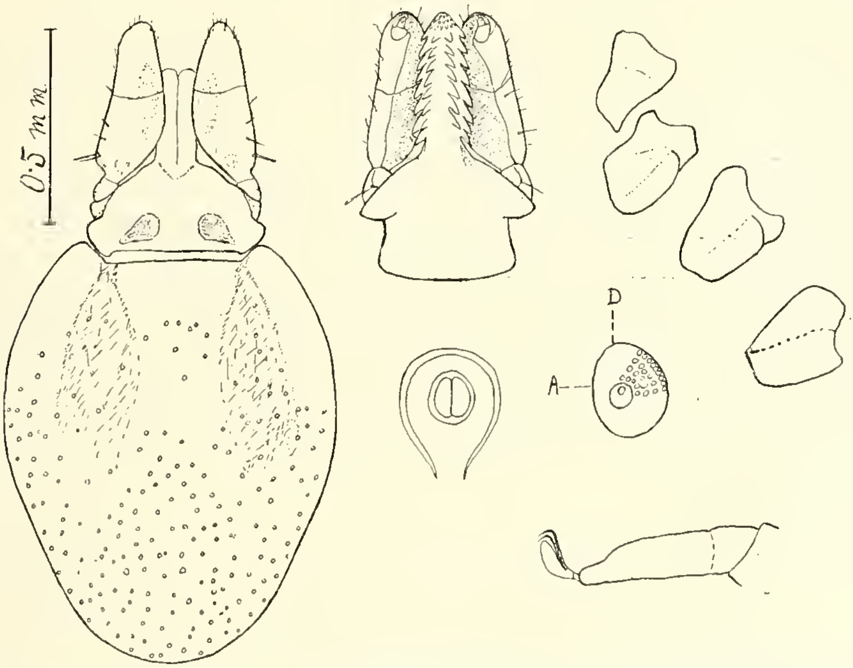

Fig. 3. *Ixodes oldi* n. sp. ♀. Capitulum in dorsal and ventral aspects, scutum, coxae I–IV, anal groove, spiracle and tarsus 4. (N. Cunliffe, del.)

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[1] Named after Dr J. S. S. Old, who has greatly aided us with material from Africa.

[2] The scutums of 8 ♀s measured 0·9 × 0·8 mm., the remaining 6 measured 1 × 0·8 mm.

with dorsal ridge straight, very slight cornua, sides protruding to form rounded angles, base compressed, rounded anteriorly, where the mandibles emerge; porose areas small, transversely ovoid or pear-shaped, concave like a saucer, the interval about equal to their shortest diameter. Palps relatively short; article 3 slightly shorter than 2, both articles slightly hollowed on the internal dorsal surface; article 1 small. (*Ventral aspect.*) Hypostome normal, 2 | 2, with 6–7 stout teeth along the outer file. Auriculae forming trenchant rounded protrusions, behind which the base grows constricted; posterior margin of base slightly rounded. *Venter*: Vulva between coxae IV or slightly anterior thereto; anal grooves horse-shoe-shaped, distinctly converging behind. Spiracles transversely oval; macula slightly excentric or central. *Legs*: Coxa I pointed postero-internally; coxae II–IV flanged, unarmed. Tarsi tapering; pad almost as long as the claws.

Described from 14 slightly engorged ♀s, found on a bush-cat, at Komatendu, Sierra Leone, West Africa, by J. J. Simpson, 13. VIII. 1912. (Imperial Bureau of Entomology, No. 604.)

This species resembles *I. lunatus, schillingsi, pilosus* and *daveyi* in possessing a horse-shoe-shaped anal groove. These species differ from *I. oldi,* however, in the following main points:

I. lunatus has armed coxae and a long capitulum; *I. pilosus* has long palps which are concave externally, and the basis capituli is of different shape; *I. schillingsi* has no lateral grooves on the scutum, the auriculae are sharp and retrograde, coxa I bears two spurs; *I. daveyi* has a long scutum without lateral ridge, long basis capituli and palps, coxae armed, etc.

It is worthy of note that all the known species of *Ixodes* possessing a horse-shoe-shaped anal groove are African: *I. lunatus* from Madagascar; *I. schillingsi* from German East Africa; *I. pilosus* from S. Africa; *I. daveyi* from Uganda; and *I. oldi* from Sierra Leone.

Ixodes ricinoides n. sp.[1]

(Fig. 4.)

Male: Unknown.

Female: Hard parts blackish-brown, as in *I. ricinus,* but the scutum may be dark chestnut coloured. (*Dorsal aspect.*) *Scutum* with moderately pointed scapular angles, longer than broad, varying between 1·6 × 1·2 and 1·4 × 1·2 mm.[1], broadest at the anterior third, rounded laterally; cervical grooves shallow, divergent, and attaining the postero-lateral border, being more or less continuous with somewhat rugose depressed areas lying between the raised central field and the lateral ridges which accentuate the lateral grooves; postero-lateral borders slightly concave where the cervical grooves end, posterior margin rounded, moderately coarse punctations aggregated chiefly in the posterior part of the median field, finer punctations chiefly upon the lateral ridges, long fine caducent hairs retained chiefly upon the antero-lateral borders and behind the emargination. *Capitulum* somewhat triangular, about as broad as long, dorsal ridge slightly concave and terminating in small, trenchant cornua; sides converging anteriorly, rounded, or with slightly marked ridge; porose areas large, somewhat pear-shaped, forming flat, coarsely punctate depressions, the interval

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[1] So named because of its general resemblance to *I. ricinus.*

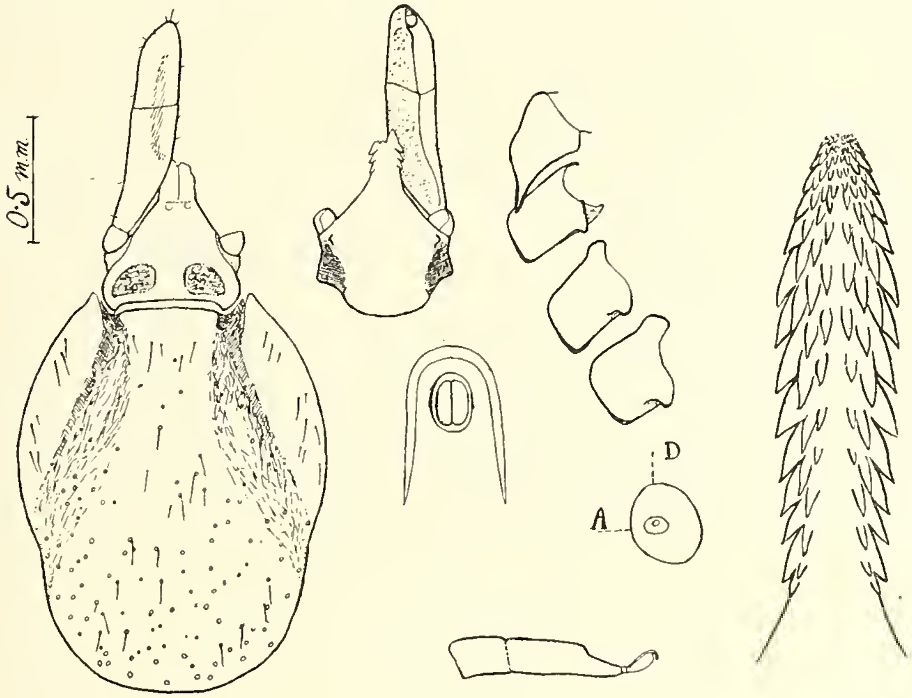

Fig. 4. *Ixodes ricinoides* n. sp. ♀. Capitulum in dorsal and ventral aspects, coxae I–IV, anal groove, spiracle and tarsus 4. The hypostome to the right is drawn as it appeared when highly magnified. (N. Cunliffe, del.)

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[1] The scutum measured as follows in the 5 ♀s:

1. 1·6 × 1·2 mm.
2. 1·6 × 1·2 ,,
3. 1·5 × 1·2 ,,
4. 1·5 × 1·2 mm.
5. 1·4 × 1·2 ,,

somewhat less than their antero-posterior diameter. Palps long, article 3 about half as long as 2, both articles slightly hollowed at the dorso-internal margin; article 1 as in *I. ricinus*. (*Ventral aspect.*) Hypostome tapering distally, 4|4, then 3|3, with 11 distinct teeth along the outer file which lies somewhat concealed behind the second file. Palpal article 1 protruding ventrally. Auriculae forming two slight protrusions and followed by a slight constriction of the base; posterior margin slightly rounded. *Venter*: Vulva between coxae IV or slightly in front thereof. Anal grooves rounded in front, fading away behind at a short distance from the anus. Spiracles transversely oval; macula central or nearly so. *Legs*: Coxa I with long pointed internal spur; coxae II–IV with stout external spur. Tarsi tapering step-wise; pad almost as long as the claws.

Described from five partially fed ♀s: one ♀ found on a *swamp deer*, Wen-chwan-hsien, near Si-ho-hsien, China, and four ♀s found on *musk deer* (same locality). The specimens, obtained by purchase from Mr T. V. Sherrin, Taxidermist, Hampton, Middlesex, are in Cambridge. (N. 1401, 1402.)

This species is allied to *I. ricinus*; the latter differs as follows:

Scutum appears shorter and more rounded; palps decidedly shorter and broader; hypostome much less tapering and shorter, dentition 3|3; spiracles sub-circular, larger in proportion to size of coxa IV; coxa I with external spur; coxae II–IV with external spur much less marked; tarsi tapering more gradually; claws longer.

PARTHENOGENESIS IN TICKS.

(PRELIMINARY NOTE.)

By GEORGE H. F. NUTTALL, F.R.S.

(From the Quick Laboratory, University of Cambridge.)

Aragão (1912) has recently described a new species of tick which he raised through three complete generations upon cold-blooded animals, the natural hosts in Brazil. He gave the species the name *Amblyomma agamum* because reproduction occurred parthenogenetically, males not having as yet been observed. The tick, in common with most other *Ixodidae,* feeds upon three successive hosts in the larval, nymphal and adult stages; it may, however, undergo metamorphosis from larva to nymph upon the host. This observation of Aragão's is the first of the kind, for parthenogenesis has not hitherto been observed in ticks. In the course of his raising experiments he obtained thousands of females which laid fertile eggs in the absence of males.

On reading Aragão's paper, it occurred to me that it would be of interest to determine if parthenogenesis occurs in ticks where males are commonly encountered with females, the sexes being usually found in equal numbers upon the host. The experiment is being tried at present with several species, a positive result having been obtained, however, with *Rhipicephalus bursa,* a common sheep tick in parts of Southern Europe and Northern Africa.

When males and females of this species are placed together upon sheep the replete fertilized females abandon the host after 4–12 days and lay 5000–7000 eggs. When we placed females alone upon a sheep they remained upon it for 25–38 days and abandoned the host without having fully gorged themselves with blood. Some of them began to oviposit after a normal interval of time and many of the eggs shrivelled up. The number of eggs laid per female is smaller (about 2000) than in females which have fed to repletion in the presence of males.

Nevertheless, from some of the eggs larvae duly emerged. Parthenogenesis, therefore, occurs in *R. bursa*, a small proportion of the eggs laid by a female giving rise to larvae.

In a paper by Oudemans (1908), to which my colleague, Mr Warburton, has drawn my attention, the author discusses the subject of parthenogenesis in Acari. According to Oudemans, Richard Beck (1866) is the only writer who appears to prove that parthenogenesis occurs in this group. If Beck's statements are true then he observed parthenogenesis in *Cheletes erudites* (sic). Berlese (1881) states his belief in the occurrence of parthenogenesis in Acari, but offers no proof as he did not carry out breeding experiments. Trouessart (1894) states that parthenogenesis occurs in *Syringobia*, but Oudemans says that Trouessart did not recognize the males.

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RECENT PROGRESS IN OUR KNOWLEDGE OF PARASITIC WORMS.

A PAPER READ AT THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. ANNUAL MEETING 1912, SECTION D.—ZOOLOGY.

By WILLIAM NICOLL, M.A., D.Sc., M.D.

(*Lister Institute of Preventive Medicine, London.*)

During the course of the last few years our knowledge of parasitic worms in all their various relations has advanced and increased to a very considerable and satisfactory extent. From the purely zoological point of view the advances have been of the highest order, many important discoveries having been made, not only in connection with the morphology but also, and particularly, in connection with the development and bionomics of these worms. At the same time there has been a steadily increasing improvement in our ideas of their classification and relationships which has resulted in a much wider and more accurate conception of their zoological nature. While these rapidly accumulating discoveries have greatly extended the knowledge at our disposal, they have, in addition, rendered such facts easier of study and of use, with the result that the economic value of the subject as a whole has been very materially enhanced. Helminthology shares with Protozoology and Entomology the, in some respects, unenviable distinction of being of intrinsic importance not only to medicine, but also to veterinary and agricultural science. It has a smaller but no less definite economic importance in relation to fisheries. Apart from their purely zoological interest it is particularly as agents of disease that the parasitic worms are of importance, but there are a number of other matters connected with habits and distribution, on which a study of parasites may throw considerable light.

There are in this way several different lines along which progress has been made. It is in many cases not a little difficult to estimate the relative importance of these advances, and it is a common experience that discoveries which appear, at first, to be of only academic interest occasionally prove of the greatest economic value. In consideration of the meeting at which this paper is being read, chief attention must naturally be paid to those features which are essentially of zoological interest and importance, but some space will also be devoted to their economic bearing. It is impossible in a short review, such as this, to deal adequately with all the work on the subject, so that, for the most part, only the work of the best known authorities will be considered.

It is frequently a matter of difficulty to determine exactly what period of time is covered by the term recent. With our present rate of advance, ideas and views change with such remarkable rapidity that any one discovery, no matter of what importance, does not long remain a novelty, and it is generally the case that those of second rate value remain entirely unknown except to a few for whom they possess an especial interest. There is the further consideration, however, that in the course of time the matters of fundamental importance become common knowledge and, I venture to think that, under ordinary circumstances, a period of five or six years will elapse before this is the case. I have accordingly chosen this as the period with which to deal.

It may be well, first of all, to consider the men who have been chiefly engaged in carrying out the work. Foremost amongst these must be mentioned the names of Looss, Fuhrmann, and Odhner, who have been mainly responsible for the great advances made in our knowledge of the flat-worms. Looss has also devoted considerable attention to the round-worms, which have received further treatment at the hands of Railliet and Henry. Amongst others whose work may be specially mentioned are Von Linstow, who has devoted himself to helminthological research for the past fifty years, Stiles, Ransom, Ward and Linton, the foremost exponents of the American School, Lühe in Germany and Goldschmidt, whose researches have been chiefly histological. In addition reference must be made to the excellent work of Porta and of Monticelli in Italy, of Weinberg in France and of Leiper, Shipley and Miss Lebour in this country. Even this long list, however, does not by any means exhaust the number of those who have specially interested themselves in the subject and have done outstanding work in it.

In dealing with such a large volume of very varied work it seems advisable to consider it, as far as possible, under separate sub-divisions, such as systematic, morphological, developmental, etc., and although many papers will require to be discussed under more than one heading, the best idea of the whole subject will probably be obtained in this way.

Considering then in the first place the systematic work, it will be found that the bulk of it has been devoted to Trematodes, in which class several of the large groups have received exhaustive treatment. The most outstanding contributions have been those on the North African Trematodes by Odhner (1911), the Echinostomes of Birds by Dietz (1910), the Distomes of North American Fishes by Linton (1910), and the important work of Looss (1907) on the Hemiuridae. Two other monographs of considerable value have been those of Stiles and Goldberger (1910) on the Paramphistomes and of Kossack on the Monostomes (1911). Of systematic work on the Cestodes the major portion has been done by Fuhrmann, the chief of whose numerous contributions is a monograph on the Bird Cestodes (1908). This work has been augmented by Ransom's monograph on the Taenioid Cestodes of North American Birds (1909). A fair amount of work has also been done on the tape-worms of Mammals by Janicki (1906). The most outstanding systematic work on parasitic Nematodes has undoubtedly been that of Railliet and Henry on the Strongyle or bursate Nematodes. In an extended series of short papers they have given the outline of a classification of these forms, which, on the whole, appears fairly successful. Their work unfortunately lacks the exhaustive character which ought to be expected in publications of such importance, and much of it will require to be gone over in greater detail. A much fuller account has been given by Ransom (1911) of the Nematodes parasitic in the alimentary canal of Ruminants. With regard to the Acanthocephala or Echinorhynchs the most extensive work has been done by Porta (1909 *a* and *b*) and by Lühe (1911). These authors have materially increased our knowledge of this very remarkable group and have devised more efficient means of identification.

The general aim of the majority of these works has been to deal with the smaller taxonomic units; the arrangement of the higher groups has not been seriously altered except in the case of the monogenetic Trematodes which Odhner (1912) proposes to divide into Monopisthocotylea and Polyopisthocotylea, basing his classification on the internal anatomy as well as the suckers, instead of entirely on the latter as has hitherto been done. On the whole, although there has been in some directions perhaps a tendency to excessive sub-divisions, the systematic work has been of the greatest value and has served as a basis for, and criterion of, work done in other departments.

Most of the works above-mentioned have dealt at the same time with faunistic and morphological questions. Very large additions have been made to the number of known species, but in consideration of the fact that only a few circumscribed regions have as yet been thoroughly investigated and that even in Europe new forms are constantly being discovered, it is evident that an enormous amount of parasitic material remains unknown. Outside Europe it is only in the United States and in the Nile Valley that a serious attempt has been made to study the parasitic fauna in general. It may be added, however, that a good beginning has been made in Australia by Miss Sweet, and T. H. and S. J. Johnston. Asia and South America remain practically untouched.

Of morphological matters only a few of the more interesting can be discussed here. One of the most remarkable of these is the discovery by Odhner (1910) of a gigantic blood-fluke in the blood vessels of a gull. It is a form closely related to the well-known human blood-fluke, but it is remarkable in possessing no suckers. This may be interpreted as an adaptation towards its mode of life, and such a view is borne out by the discovery of another blood parasite, possessing the same peculiarity, but not otherwise at all closely related to the former, namely *Sanguinicola*, a parasite of fishes. By its discoverer it was at first regarded as a Turbellarian and later as a Monozootic Cestode. A separate order, indeed, was created for its reception. Odhner (1911), however, showed that it is in reality a digenetic Trematode, and that a closely related form, *Aporocotyle*, was known as long ago as 1900. Further interest in this matter has been stimulated by Linton's discovery of a similar form, *Deontacylix*, in an American fish. All these forms present a great resemblance to Monozootic Cestodes but differ from them in possessing an alimentary canal. Another remarkable discovery in Trematode anatomy was made by Leiper (1908) to the effect that in a curious new avian Echinostome (*Balfouria*) there is communication between the intestine and the excretory bladder. This observation was confirmed by Odhner (1910), who found the condition present not only in *Balfouria* but also in another allied species, and in a widely different genus of fish Trematodes (*Haplocladus*). A further case is reported by Looss (1912). Odhner interprets the condition as the formation of a secondary anus. This discovery will involve a revision of the generally accepted belief that the Trematode intestine usually ends blindly, and probably not a few other cases will be discovered. The above-mentioned genus *Haplocladus* offers the further peculiarity that it has only one asymmetrical intestinal coecum instead of the usual symmetrical pair.

Another important contribution to the anatomy of the flat-worms was made by Goldschmidt (1909) and extended by Von Hofsten (1912). It relates to the function of the so-called shell-gland which has hitherto been believed to be the active agent in producing the material for the egg-shell. It has, however, been shown by these authors that this function is actually performed by the yolk-gland cells which contain the shell substance in the form of small droplets. This substance is liberated in the ootype and it is not impossible that the secretion from the shell-gland may have some influence in causing this liberation. It is further shown that the yolk-cells possess little nutritive function.

The old question of the homology of Laurer's canal in the Trematodes and Cestodes has been raised anew by Odhner (1912), who maintains that the original view of Stieda is the correct one and that Looss' later view cannot be admitted. The latter view, which has received acceptance of late, is that Laurer's canal in the digenetic Trematodes is the homologue of the functional uterus in the Cestodes. This is a view that does not bear very critical investigation and from the topography of the "shell-gland complex" Odhner concludes that the real homologue is the Cestode vagina. On the other hand, in the monogenetic Trematodes Odhner denies that the gastro-intestinal canal is the homologue of Laurer's canal; he regards it as a structure *sui generis*. In certain of the Monogenea the functional vagina is undoubtedly the homologue of Laurer's canal, in others it is entirely absent. This is not remarkable in view of the fact that Laurer's canal is frequently absent in the Digenea. Odhner has also introduced the new term "ductus vaginalis" to designate the duct leading from the paired vaginae into the yolk-duct in the Polyopisthocotylea.

An important contribution to our knowledge of the excretory system of Platyhelminths has been made by Willem (1910), while many new structural details of the Amphistomes have been investigated by Stiles and Goldberger (1910). The descriptive scheme advocated by Stiles has not found general acceptance and it is doubtful if it will be much used outside America. According to this scheme the Trematode body is divided into hypothetical zones and fields, bounded by lines passing through fixed points and the internal anatomy is described in relation to these. The terminology, it may be remarked, is not pretty, while the new method is not less cumbrous than the old one and is hardly so exact.

On the Cestodes the most interesting work, perhaps, is that by Cohn (1906 and 1911), Kofoid and Watson (1910) and Watson (1911) on the orientation of the Cestode strobila. From the detailed study of the nervous system these authors come to the conclusion that the scolex or so-called head of a tape-worm is really the posterior end. Valuable work has also been done by Gough (1911) on a group of Cestodes which he has formed into a sub-family Avitellininae, characterised by the absence of yolk-glands. Interesting work on the histogenesis and cytology of the Cestodes has been accomplished by Young (1910) and Richards (1911).

With regard to Nematodes the most remarkable work is that of Looss (1905–1911) on the anatomy of the hook-worm (*Agchylostoma duodenale*), of Goldschmidt (1908–1911) on the nervous system of *Ascaris*, and of Martini (1908 and 1909) on the sub-cuticula and lateral fields of Nematodes. Looss' monograph is probably one of the most exhaustive ever written on a single species. Goldschmidt's work is no less remarkable. He has traced out the entire nervous system of *Ascaris lumbricoides* and *A. megalocephala* to its finest ramifications, and has shown that it is constant in arrangement. He has also been able to show that the nerve cells in *Ascaris* do not multiply but simply increase in size as the animal grows older. Another paper which appears worth mentioning here is that of De Baillon (1911) on the muscle fibres of *Ascaris*.

Passing on now to a consideration of the bionomics of these forms and dealing first with the early life-history we find that several interesting matters have been investigated. For instance there is the discovery of the intermediate host of the Japanese liver-fluke (*Clonorchis endemicus*) by Kobayashi (1910 and 1911). Some of the credit of this discovery is due to Askanazy (1906). This fluke passes its intermediate stage encysted in certain fresh-water fishes and infection is acquired by eating these. There is also the discovery of the mode of infection of the Japanese blood-fluke (*Schistosomum japonicum*) by Katsurada and Hashegawa (1910). It is some years since Looss advanced the hypothesis, based on circumstantial evidence, that the blood-flukes have no intermediate host and that infection takes place through the skin. The work of Katsurada and Hashegawa has demonstrated experimentally the correctness of Looss' views. Perhaps the most important other contributions to Trematode development is that of Haswell (1909) on

Temnocephala. Practically nothing of very great moment has been done on the development of the Cestodes apart from the already mentioned work of Young (1908) on histogenesis in Cysticerci, and of Child (1907) on the development of the germ cells in *Moniezia.* Perhaps the most interesting detail in life-history is the discovery of further cases of fleas acting as intermediate hosts of tape-worms. The new observations were made by Dampf (1910) and Nicoll and Minchin (1911). Altogether four cases are now known, namely, the dog tapeworm (*Dipylidium caninum*), the rat tape-worm (*Hymenolepis diminuta*), and two others of which the adult forms are not definitely known.

The most important work on Nematode development is without question that of Looss (1911) on the human hook-worm (*Agchylostoma duodenale*). In a very exhaustive monograph he has dealt with practically all the points of importance in the life-history of this exceedingly formidable parasite. It is impossible to refer in detail to all the questions discussed by Looss, many of which, indeed, have a wide bearing on the general subject of Nematode development. The most vital facts are that the larva of this worm can enter its host by penetrating the unbroken skin, and that in the life-cycle there is no heterogenesis or double sexual cycle. The original statement of both these facts dates from an earlier period than we are considering here, but they have been so seriously criticised during the intervening years that only now can they be regarded as having received absolutely irrefutable confirmation. Another classical Nematode, of which the life-history has been established, is the Guinea-worm (*Dracunculus medinensis*). We owe our knowledge of the life-history of this worm to the researches of Fedtschenko, Graham, and most recently, Leiper (1906). In the last place mention must be made of the very considerable amount of general cytological and developmental work which has been done upon *Ascaris,* the most outstanding being that of Zur Strassen (1906) and Martini (1906).

There remain for consideration several scattered observations on the bionomics of parasitic worms in general. Of these only a few can be mentioned here. Some interesting notes were made by Jammes and Martin (1908, 1909 and 1910) on the conditions of development of Nematode eggs. They found that the egg-shell is practically impermeable, except to gases, at ordinary temperatures, but when the temperature is raised the impermeability is modified and several substances such as hydrochloric acid, sodium carbonate, etc., are able to permeate. They also found that Nematode eggs may be classified according to the temperature at which they develop best, some only developing at a temperature lower than that of the host, some being relatively indifferent and others doing best at the temperature of the host. In this way they read an evidence of the manner in which parasitic Nematodes have become adapted to their modes of life. Hamill (1906) has confirmed the earlier view of Weinland that there is in *Ascaris* an antibody which resists tryptic digestion. This question of the nature of the substances secreted by parasitic worms is a very wide one and has called forth a considerable amount of work. The idea of toxins has bulked largely in medical literature dealing with the subject, but, although there is a *prima facie* element of reason in the idea, no satisfactory experimental or clinical demonstration of a general nature has yet been forthcoming. The most important of recent work on this matter is that of Flury (1912) and Weinberg (1912). Another matter which may be most appropriately referred to here is that of the formation of pearls by parasitic worms in their larval stage. This was first brought into prominence about ten years ago by Jameson who showed that pearls in the common edible mussel owed their origin to the presence of larval Trematodes. A few years later Herdman and Hornell advanced the view that Ceylon pearls had a similar origin, the agent in this case being a larval tape-worm (*Tetrarhynchus*). This view has led to an economic attempt to encourage the presence of this tape-worm on oyster beds so as to increase the yield of pearls. Doubts, however, have been cast on the correctness of these observations by Jameson (1912) who considers that some other causal agent must be sought for in the case of the Ceylon pearl oyster.

Coming now to a consideration of the economic, and more particularly the medical relations of parasitic worms, we find that many problems involving the health of both men and animals have been extensively investigated and that a fair measure of improvement has resulted. The disease which has attracted most attention during these latter years is Schistosomiasis or Bilharziosis. This is the particularly intractable disease due to the presence of blood-flukes (*Schistosomum*) and although not so notorious or widespread as Ankylostomiasis or Filariasis it is usually more difficult to treat and indeed no cure has yet been discovered. The chief work done in regard to the Egyptian form of the disease has been of a clinical and pathological nature by Goebel (1907), Glaesel (1910) and Letulle (1911). These contributions, although they have served to fix a definite pathological picture of the disease, have not added materially to our knowledge of the subject. A more important contribution is that of Katsurada and Hashegawa, already referred to, on the mode of infection. Another question of some moment is the possibility of the existence of a second species of *Schistosomum* in Egypt and of yet another in South America, both differing from the ordinary form in the possession of lateral-spined eggs. Sambon (1909) and Da Silva (1908 and 1909) have supported this contention, but it has been strenuously opposed by Looss (1911) who maintains that one and the same species produces both varieties of eggs and that the variations have their origin in the egg-producing apparatus. As far as can be judged, Looss' view appears to be the more probable one.

Probably no parasitic disease, other than malaria, has aroused such widespread interest or has called forth such a mass of literature as hook-worm disease (Ankylostomiasis). It was a remarkable discovery, indeed, that the greater bulk of the very numerous cases of tropical anaemia was due to the infection with the hook-worm. The worm itself was discovered about 70 years ago, but little was known regarding it for 40 years, and it was not until 15 years ago, when Looss started to deal with the subject, that the material points in the life-history began to be known. Reference has already been made to Looss' conclusive monograph which summarises practically all our present knowledge on the subject from the biological side. It is impossible to discuss here the numerous medical contributions which have been made regarding treatment, prophylaxis, and so forth, but reference must be made to the Milroy Lectures (1911) by Boycott, who, in association with Haldane, did much good work in studying the disease as it occurred in this country in the Cornish tin mines.

Hydatid disease, again, has furnished the subject of much investigation. Occurring as it does, not only in man, but also in many of the domesticated animals it has been dealt with extensively both by medical men and by veterinarians. In Germany it has formed a favourite subject for Theses and Dissertations, the most considerable of which is that by Becker (1907). The most noteworthy results have been achieved in two directions, first by Dévé (1907–1912) who has studied the experimental production of hydatids, and secondly by Weinberg and numerous others who have been concerned with a means of diagnosing the presence of the disease, which is an extremely difficult matter by ordinary clinical methods. To Weinberg undoubtedly belongs the chief credit of utilising a method of diagnosis which gives promise of being a reliable and useful aid to medicine, namely, the serological method. Serum-diagnosis is one of the most recent of medical methods and has been found of great use in a number of diseases which owe their origin to specific organisms. The presence of these organisms causes the production of certain antibodies in the blood. It is then found that the blood serum gives a definite reaction with an extract made from the parasite. More than one variety of reaction can be made use of, but the most invariably successful is that known as complement deviation. No method is absolutely unimpeachable, but this one has been found correct to the very considerable extent of 90 % of cases. A useful monograph and review of the whole subject has been written by Pfeiler (1911).

Of a different nature is the work done by Tallquist (1907) on the anaemia produced by the presence of the broad tape-worm (*Dibothriocephalus latus*). This parasite occurs particularly in Finland and the adjoining region, although it is known in all parts of Europe and it gives rise to a very severe and fatal form of anaemia. In view of the fact that our present knowledge of the causation of anaemia is extremely limited, the work of Tallquist is of great importance. It is a widely accepted hypothesis that anaemia, in general, is caused by some poisonous substances finding their way into the blood and causing destruction of the blood cells or of the tissues from which they are formed. Tallquist's work supports such a view in this particular case, for from the tape-worm he extracted poisonous substances which, when injected into the blood of healthy animals, caused marked anaemia. That is practically as far as he was able to go, but it represents a very material advance.

Another matter which has received a very considerable amount of attention is the relation of worms to intestinal diseases in general and, in particular, to appendicitis, enteritis, typhoid fever and dysentery. The chief exponent of this line of investigation is Guiart (1910) who has brought forward a large amount of evidence together with not a little hypothesis in support of the view that intestinal worms may be the predisposing, if not the chief, cause of some of these diseases. Similar views have been advocated by Shipley (1909) in this country. They have been supported by a number of observations, chiefly in reference to appendicitis, and are to the effect that in cases of this disease thread-worms are frequently found in the appendix. The theory is that the worms injure the wall of the appendix and lead to the invasion of pathogenic bacteria. The most important and thorough contribution to this subject has been made by Garin (1911) who has found that the whip-worm (*Trichuris trichiura*) damages the intestinal mucosa and is certainly responsible for a large proportion of cases of intestinal inflammation. It is not a little difficult to estimate the exact value of these observations in general. One is quite prepared to believe that worms exercise a harmful influence in the intestine and that they may aid in causing disease when the necessary other factors are present, but that they are in themselves a specific cause of inflammatory lesions is opposed to present bacteriological views. It must not be forgotten that such worms as are incriminated, namely *Ascaris lumbricoides*, *Oxyuris vermicularis* and *Trichuris trichiura*, are extremely common amongst certain classes of the community and that as a rule they give rise to few symptoms. Their frequent occurrence, therefore, in cases of disease which are brought under notice, is not to be wondered at. There is a certain element of coincidence, moreover, for *Ascaris lumbricoides* and typhoid fever, for instance, are both correlated with the same insanitary conditions.

Passing on now to diseases of animals. I would specially select two which have aroused interest and concern in this country. The first of these is grouse disease. For many years, even for at least a century, the grouse of this country have been subject to severe periodic epidemics of disease. These occurrences give rise to much speculation, but it was not until 1865 that an earnest attempt was made to thoroughly investigate the matter. The result of that investigation provided two conflicting opinions, namely that of Klein who held that the disease was of bacterial origin, and that of Cobbold who showed that parasitic Nematode worms were a very likely cause. The recent commission on grouse disease has made a very thorough study of the disease, and the results published last year have demonstrated the correctness of Cobbold's views. The parasite in question is a Strongyle worm (*Trichostrongylus pergracilis*) which infects the coeca in enormous numbers. Chief credit in this work is due to Shipley and Leiper, who have made a careful study of the anatomy and life-history of the parasite.

Another disease which has caused considerable uneasiness in this country is what is known as Onchocerciasis or worm nodules in cattle. This was first brought into prominence by its discovery in frozen carcases imported from Australia. It was the subject of much alarm and called forth a special inquiry by the Local Government Board. Leiper (1911) succeeded in demonstrating the exact nature of the disease and its harmlessness to man. The nodules are caused by parasitic Nematodes of the Filaria family, namely *Onchocerca gibsoni*. The parasite does not apparently injure the health of the animal, but it renders the meat unsightly. It does not infect man though it is closely allied to a similar human parasite. Earlier investigations had been carried out by the Australian Authorities at Sydney and Melbourne and full reports were published by Cleland and Johnston (1910) and Gilruth and Sweet (1911). The life-history of the parasite, however, is still a mystery, and until that is known little can be done towards eradicating the disease.

Of the other diseases of domesticated animals probably most work has been done on Trichinelliasis in pigs and Sclerostomiasis in horses, but not much of it has been of an outstanding character. One of the most interesting new facts disclosed is that the faeces of swine infected with *Trichinella* are infective for other animals. This statement was made by Ressling (1910) and confirmed by Raebiger (1911). Such a fact introduces an anomaly into the life-history of this parasite, which had not hitherto been suspected, and it is of great importance from an epidemiological point of view as it largely increases the chances of infection.

It may be of some interest to give a brief account of the new worm parasites which have been added to the already long list of those infecting man. Within the period under consideration 11 new forms have been discovered. Many more have been described as new but have been found later not to be so. Of the total number four are flukes, four tape-worms and three Nematodes. The new flukes are *Fasciolopsis fülleborni*, *F. goddardi*, *Echinostomum ilocanum* and *E. malayanum.* With regard to the first two there is considerable controversy as to whether they are really distinct from the better known species *Fasciolopsis buski*, and the question must still be regarded as unsettled. There seem to be well-marked differences between these forms at the time of collecting but beyond that we have no structural details. The new tape-worms are *Taenia bremneri*, *Dibothriocephalus parvus*, *Diplogonoporus brauni* and *Braunia jassyensis.* Of these the last is the most interesting. It is the first representative of the Liguline tape-worms ever found in man, and is characterised by being unsegmented externally. The new Nematodes are *Lagochilascaris minor*, *Agamofilaria georgiana* and *Physaloptera mordens*, of which the last mentioned is probably the most interesting.

THE BIOLOGY OF SOME NORTH AMERICAN TICKS OF THE GENUS *DERMACENTOR*[1].

BY F. C. BISHOPP AND H. P. WOOD,
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(With Plates X to XII, and 1 Map.)

NO group of ticks presents a more interesting biological study than the genus *Dermacentor*. The diversity of habits of these ticks is remarkable. These differences in habits, especially when we find them correlated with certain structural characteristics, would lead some to consider splitting the genus into two or more genera or subgenera. This we do not think well advised.

In North America we find more species of the genus *Dermacentor* than in any other part of the world, there being at least eight valid species[2] and one variety. The species of the genus may be divided into two groups, based on their habit of moulting on or off the host.

The group which moults on the hosts is composed of *nitens*, *nigrolineatus* and *albipictus*. *Dermacentor nitens* shows the highest specialization in habits. It attaches itself almost exclusively in the ears of the host and has a limited host relationship. This species has circular stigmal plates with a few large goblets, and it is devoid of white marking in both sexes. *D. nigrolineatus* has oval stigmal plates (Pl. X, fig. 9 ♂; fig. 8 ♀) with only a suggestion of a postero-dorsal prolongation and comparatively few (many more than *nitens*) large goblets; it is also unmarked with white. *D. albipictus* (Pl. X, fig. 5 ♂; fig. 6 ♀) has larger goblets than *nigrolineatus*, and the stigmal plates have a more or less decided tendency toward a dorso-posterior prolongation; the scutum of this species is banded with white, but these markings are often yellowish and not intense.

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[1] Published by permission of the Chief of the Bureau of Entomology.

[2] We are in doubt about the status of *Dermacentor salmoni* Stiles (*Bull.* 62, *Hygienic Lab., U.S. Pub. Health and Marine Hospital Service*, pp. 55–60, 1910), but are inclined to regard it as but a variety of *D. albipictus* Packard.

In the group which moults off the host we find *hunteri, parumapertus, parumapertus* var. *marginatus, venustus, occidentalis* and *variabilis*. In all but *variabilis* the stigmal plates have a prominent dorso-posterior prolongation, and the goblets are numerous and much smaller than in members of the previous group. *D. variabilis* has broad stigmal plates, with a short, broad dorso-posterior prolongation and many exceedingly small goblets. All of the species in this group except *parumapertus* have extensive, intense white markings on the scutum.

Economically this genus is of considerable importance in the United States, as all of the species are of some economic significance except *D. parumapertus, D. parumapertus* var. *marginatus,* and *D. hunteri.* The first two ticks have not been found to attack any host other than rabbits, and the last has been taken only on the mountain sheep. *D. variabilis* is of little economic importance, so far as known, because among the domestic animals it most commonly attacks the dog. However, it is sometimes taken on the larger domestic animals and occasionally attaches itself to man. *D. occidentalis* and *D. venustus* are common pests of man and nearly all domestic animals, and the latter species, as is well known, is the transmitter of the disease of man called Rocky Mountain spotted fever. The other three species—*nitens, albipictus* and *nigrolineatus*—are each of considerable importance as live stock pests; none of these are known to attack man.

The life histories of all of the previously mentioned species (except *D. parumapertus* proper) have been worked out during the investigations conducted by the Bureau of Entomology. The more important facts thus obtained, appertaining to the distribution, life histories and habits of *nitens, occidentalis, parumapertus* var. *marginatus, variabilis* and *venustus* have been published[1].

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[1] Hunter, W. D. and Hooker, W. A. Information concerning the North American fever tick, with notes on other species. *Bull.* 72, *Bureau of Entomology, U.S. Dept. Agr.* pp. 49–52, 1 pl. 2 figs. Nov. 2, 1907.

Hunter, W. D. and Bishopp, F. C. Some of the more important ticks of the United States. *Yearbook, U.S. Dept. Agr. for* 1910, pp. 225–228, 1 pl. 1911.

Hunter, W. D. and Bishopp, F. C. The Rocky Mountain spotted fever tick. *Bull.* 105, *Bureau of Entomology, U.S. Dept. Agr.* 47 pp. 3 pls. 3 figs. Nov. 17, 1911.

Hooker, W. A., Bishopp, F. C. and Wood, H. P. The life history and bionomics of some North American ticks. *Bull.* 106, *Bureau of Entomology, U.S. Dept. Agr.* pp. 21–37, 70–71, 158–204, 5 pls. 5 figs. Sept. 7, 1912.

In the present paper the authors present biological notes on *albipictus, hunteri* and *nigrolineatus.*

The work upon which this paper is based was done under the auspices of the Bureau of Entomology, United States Department of Agriculture, in the section of Southern Field Crop Insect Investigations, in charge of Mr W. D. Hunter. To Mr Hunter we are indebted for aid in the carrying on of the investigations and for helpful suggestions. Our thanks are due to Mr W. V. King, of the Bureau, who has made notes on the occurrence of this species in the Bitter Root Valley in Montana, and collected some of the material used in our work. We wish to express also our appreciation of aid contributed by Professor R. A. Cooley, of the Montana Experiment Station, for records of collection and specimens from several localities in Montana. No little assistance has been afforded by many correspondents who have forwarded material and made records for us on ticks in several localities.

Dermacentor hunteri[1] Bishopp.

Distribution.

This species has been taken only in Arizona, near Quartzsite, and Supai. The type is from the former locality. There the hosts, mountain sheep, range from the higher points of the mountains (about 3000 feet altitude) to the Colorado river (altitude 200 feet) where, according to statements by Mr George Hutson, they may be found watering in June and July. All of the specimens collected were found on hosts taken between 1500 and 2500 feet altitude. Mountain sheep have not been examined for ticks in other localities, hence the distribution of this species is not definitely known.

Hosts.

The type host, the mountain sheep (*Ovis canadensis gaillardi* Mearns), is the only animal upon which this tick has been collected. No specimens of this species were found as a result of examinations of other animals, including domestic stock, in the locality where the tick was found. None of the immature stages of the species have been taken in nature, but it is probable that they engorge on small wild mammals. In the laboratory the larvae, nymphs and adults were fed on guinea-pigs. Two slightly engorged females, collected on mountain sheep and sent to Dallas, Texas, were kept in a sack on the scrotum of an angora goat for three days, but neither became attached; but when they were placed upon a guinea-pig they attached themselves immediately.

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[1] The mountain sheep tick is suggested as a common name for this tick, as this appears to be the principal, if not the only, host of the adults of the species.

Seasonal History.

All the information which we have regarding the seasonal history of this tick is our records of collections, all of which were made by Mr George S. Hutson, of Quartzsite, Arizona. These lots were collected in July, August, September and December. The collections indicate that most of the females become engorged and drop off the hosts during the fall and winter. All the following records were made at Quartzsite, Arizona: 3 ♂ (a dozen or more specimens, probably not engorged, were collected, but not sent in), July 8, 1910; 16 ♂, 1 ♀ (unengorged), August 10, 1910; 5 ♂, 2 ♀ (unengorged to $\frac{1}{20}$ engorged), August 20, 1910; 18 ♂, 13 ♀ (unengorged to fully engorged), December 1, 1910; 23 ♂, 12 ♀ (unengorged to $\frac{1}{20}$ engorged), September 2, 1911. Several specimens, mostly males, escaped when the last collection was being made.

Life History and Habits.

Oviposition: No records have been made under natural conditions on the pre-oviposition period. Two females ($\frac{1}{3}$ and well engorged) taken from a host December 1, 1910, were received at Dallas, December 7, and put into an incubator at a mean temperature slightly above 90° F. These began to oviposit about December 11, and completed oviposition in nine days, having deposited about 1000 and 2500 eggs respectively. The eggs are deposited in masses as in other species of Ixodidae.

The process of oviposition was not observed, but an engorged female was seen extending and retracting the *vesica biloba*[1], though no eggs were laid. She afterwards died without ovipositing and with the *vesica biloba* extended. This organ does not differ materially in structure or appearance from that observed in other ticks. When the lobes are extended they appear like tapering fingers, the tips being curved ventrally so as to rest on the dorsal surface of the basis capituli or palpi, according to the distance they are extended. They are transversely wrinkled. The basal part of the organ is distinctly bilobed dorso-ventrally, this division showing slightly dorsally. In the specimen observed there was a large amount of viscid secretion on the mouthparts and *vesica biloba*, and the anterior half of the scutum was covered with this waxy secretion.

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[1] Termed *Gené's organ* by Nuttall 1908; see also Robinson and Davidson (IV. 1913), *Parasitology*, VI. 34, and their paper appearing in the next number.—Ed.

The Egg: The eggs are ovoid in shape, and light to dark brown in colour, with shining surfaces. No counts to determine the exact number of eggs deposited by this tick have been made. Their number and the appearance of the mass are practically the same as in *D. venustus.*

Three lots of eggs were observed to determine the incubation period. Two of these lots were kept in an incubator at an average temperature of about 90° F.; the other was kept in the laboratory. All the lots were in tubes containing moist sand. The first two lots began to hatch in 14 days, and all of the larvae appeared to have emerged in less than 12 days after hatching began. The third lot, consisting of 50 eggs deposited about January 1, 1911, shrivelled up and failed to hatch.

The Larva: The habits of the larvae appear to be very similar to those of *D. venustus.* During most of their existence, after the first two or three weeks following hatching, they remain more or less scattered and crawl about much. The period after hatching is spent mainly in dense bunches near the ground.

In one test of the longevity of larvae, in a bunch of about 1000 larvae which began hatching December 25, 1910, the last individual died about March 5, 1911, having lived for a period of 70 days. In another lot consisting of about 2500 larvae which began hatching on the same day, on March 17, 20 larvae were still alive and some of them were able to attach themselves to a host. Hence the longevity of larvae hatched at this time may exceed 82 days. These lots were kept in the laboratory in tubes which had moist sand at the bottom.

Only one record of larval engorgement has been made. In this test 20 larvae (weak) were placed on a guinea-pig March 17, 1911. At least six of them became attached but died without engorging. The only one which became engorged dropped off on March 27, thus showing an engorgement period of ten days.

This engorged larva measured 301 microns long, 215 microns wide and 151 microns thick. The abdomen was deep wine coloured and shining; the legs and capitulum pale yellow and translucent; the scutum brownish-yellow, darkest posteriorly.

On April 19, 23 days after dropping off the host, this larva moulted to a nymph. During this period the mean temperature in the laboratory, where the larva was kept, was 75·3° F.

The nymphal tick escaped by crawling forward and to one side after the larval skin had been ruptured. The skin split from a point posterior to the hind coxae along the margins of the tick slightly above the coxae, then the break turned dorsally at the anterior end so as to reach the scutum near the eyes. From these points the fissures extended posteriorly along the margin of the scutum to its tip where the two ruptures met. The exuvium was left firmly attached by the tarsal claws. The abdominal portion was almost white and the highly chitinised portions changed little in colour compared to those of the larva.

The Nymph: Little has been learned regarding the habits of the nymph, as only one nymph has been observed. This individual moulted from the larval stage on April 19, 1911. On May 12, 1911, it was placed on a guinea-pig. It became attached readily and five days later was noticeably larger. At this time a number of small pellets of excrement were observed in the hair beneath the tick. On May 18 the nymph was $\frac{1}{3}$ to $\frac{1}{2}$ engorged and the abdomen had taken on a dark bluish-gray colour. The subsequent evening at 7 o'clock it appeared to be fully engorged. On the morning of May 20 it was found to have dropped from the host, having had an engorgement period of $7\frac{1}{2}$ days. The measurements of this individual were: 4·9 mm. in length (including capitulum), 2·7 mm. in width, and 1·6 mm. in thickness. The body was slate coloured; the scutum reddish-brown anteriorly, darker at tip; and the legs, coxae and capitulum, light reddish-brown.

This nymph transformed to a male on June 12, 1911, or 23 days after dropping off the host. During this period the mean temperature was 86·5° F.

In moulting the nymphal skin ruptured immediately above the stigmal plates on either side. These splits extended posteriorly along the ventral ends of the festoon grooves, and met at the posterior end. They also extended anteriorly and dorsally until opposite the first coxae, when the rupture ran dorsally on either side to a point on the scutum near the eyes. The tick then escaped through the posterior end of the skin. As the tick escaped two ruptures ran dorsally from the primary fissure along the first festoonal grooves on either side. These extended up to the marginal groove and the portion of the integument bearing the festoons was raised up, bending hinge-like along the marginal groove. This process of moulting, as well as that observed in the larva, is practically identical with that which we have observed to occur in other Dermacentors which moult off the host.

The Adult (Pl. X, figs. 1–4): A few tests of adult longevity have been made. The ticks used were individuals collected on hosts in nature. One female, about $\frac{1}{10}$ engorged, lived 117 days. Another female in a lot containing several specimens lived 111 days. At the end of this time she attached herself to a guinea-pig but was later shaken off and killed.

One female only has been engorged experimentally. This was one of two females which were collected on September 2, 1911, on a mountain goat. They were about $\frac{1}{25}$ engorged and may have been fertilised. They could not be induced to feed on an angora goat, but quickly attached themselves to the ear of a guinea-pig when applied on September 21. One of the ticks was shaken off but reattached itself, only to be dislodged again. This time it received an injury which caused its death. The remaining tick showed considerable increase in size on September 25, and on the 27th it was over $\frac{1}{2}$ engorged. On the morning of September 28 it appeared fully engorged. It dropped off that evening at 6 o'clock, being well engorged (measuring 11·2 × 6·3 × 4·7 mm., the length including the capitulum in normal position). The body was dark bluish-gray in colour. This tick remained active until about October 21 when it died. On October 5 and the following five days it was seen to protrude the *vesica biloba* as though about to oviposit, but no eggs were deposited.

The largest female which we have seen was collected on a mountain sheep. It measured 12·9 × 7·5 × 4·2 mm. (length including capitulum).

The predominance of males, especially in the summer months, indicates that they remain on the host for some time after the females drop off.

Economic Importance.

This tick has not been collected on domestic animals and it is of no known economic importance. The infested mountain sheep examined were apparently healthy and the one which bore the greatest number of ticks (probably 35 specimens) was in fine condition.

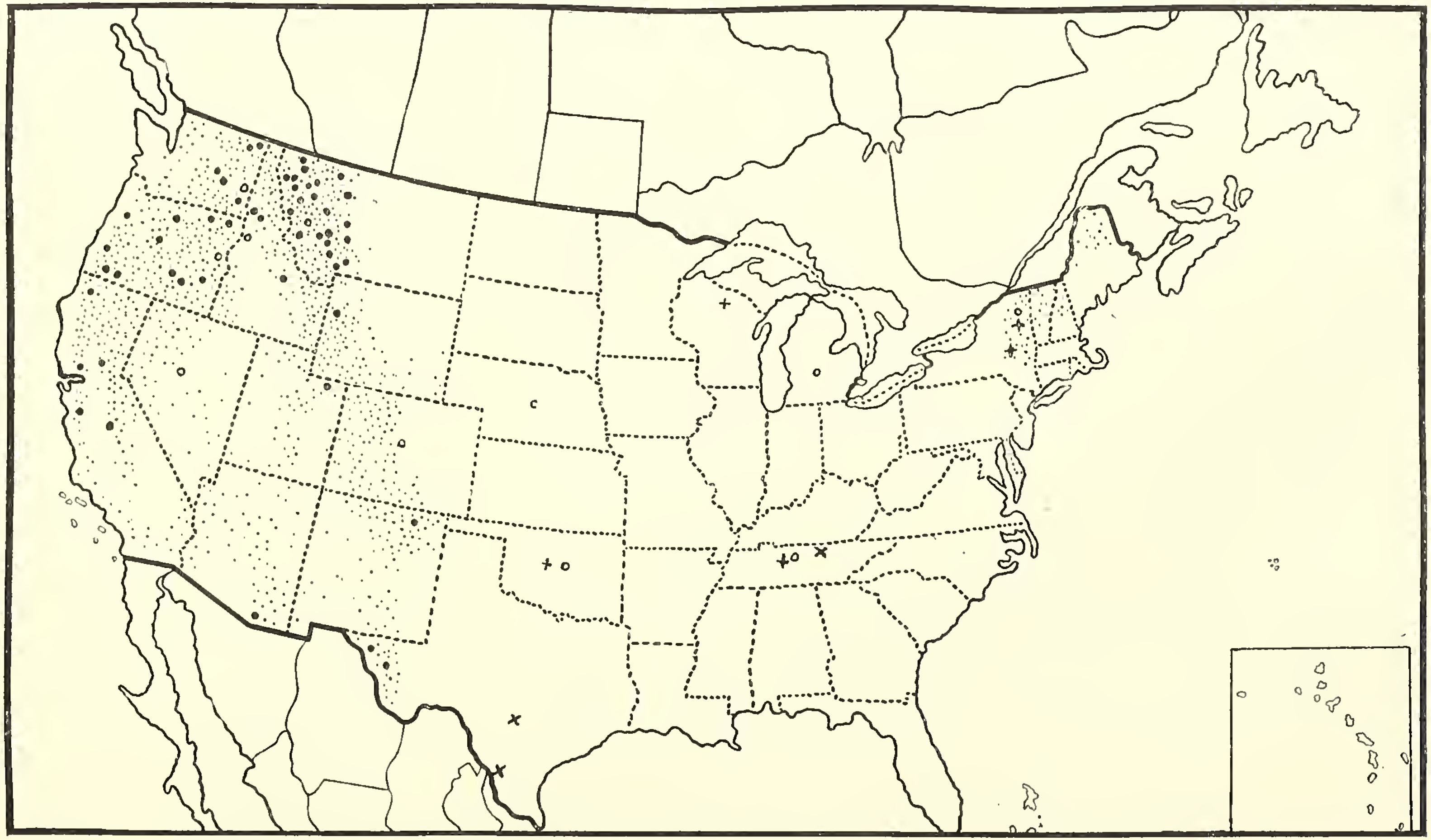

Fig. 1.

Fig. 1. Map showing the distribution of *Dermacentor albipictus* and *Dermacentor nigrolineatus* in the United States.

Black dots indicate the localities in which *D. albipictus* has been collected during this investigation.

Small circles show records by other investigators of the occurrence of *D. albipictus*.

Small points indicate the probable normal distribution of *D. albipictus* in the United States.

× marks indicate the localities in which specimens of *D. nigrolineatus* have been collected during this investigation.

+ marks indicate localities where *D. nigrolineatus* has been collected by other investigators.

Dermacentor albipictus[1] Packard.

Distribution.

Banks reports[2] having seen specimens of this species from the Adirondack Mountains, New York; Michigan; Nebraska; Montana; Bear, Idaho; Nevada and Pullman, Washington. The types are from Nova Scotia, Canada. Stiles records[3] specimens from Blue Mountain, New Hampshire. If we consider *D. salmoni* Stiles as belonging to this species, his records[4] of a collection in Oklahoma, one from Nashville, Tennessee, and one from Montana should be included. We are inclined to the belief that the ticks collected in Oklahoma and Nashville, Tennessee, were imported on hosts into these localities and are not to be found normally in these districts. This is probably true also of the record from Nebraska. A good example of how this tick may be accidentally introduced into a locality or collected on transient animals has recently come to our attention. Specimens were collected on cattle at Fort Worth, Texas, by Dr Irwin Owens. These cattle were shipped from Marathon, Texas, a distance of over 600 miles. Hall[5] has reported two collections of ticks, which are probably this species, taken in eastern Colorado.

During our investigations a fairly accurate knowledge of the distribution of this tick in the Western States has been obtained. The accompanying map (Fig. 1) indicates the points from which we have obtained specimens, as well as the probable distribution of the species in the United States. Little is known regarding its distribution in Canada, although it undoubtedly occurs commonly in much of the southern part of the Dominion. Dr C. Gordon Hewitt states, in his report for 1911 (p. 225), that this tick was taken at Huntingdon, B. C., from a horse which had been imported from Elgin, Oregon; also in Quebec from elk brought from Wyoming. The following are the localities, arranged by States, from which we have received specimens during these investigations:

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[1] The common names of "Moose tick" and "Elk tick" have been applied to this species. As these names are but little used, and we believe a more distinctive name should be applied, we suggest "Winter tick" as a common name.

[2] "A revision of the Ixodoidea of the United States." *Tech. Ser. Bur. of Ent., U.S. Dept. Agr., Bull.* 15, p. 44. 1908.

[3] "The taxonomic value of the microscopic structure of the stigmal plates in the tick genus *Dermacentor*." *U.S. Pub. Health and Mar. Hosp. Service, Hygienic Lab.* 1910, *Bull.* 62, p. 63.

[4] *Ibid.* pp. 57–60.

[5] "The parasitic fauna of Colorado." *Colorado College Pubs. Sci. Ser.* Vol. XII. No. 10, p. 366.

Arizona: Patagonia.
California: Coarsegold, Glen Ellen, Grass Valley, Hollister, Yocumville.
Idaho: Myers Cove, Nezperce, Waha.
Montana: Aldridge, Canton, Cascade, Dupuyer, East Helena, Elizabeth, Eureka, Florence, Fridley, Hall, Jocko, Lo Lo, Paradise, Plains, Pony, Rimini, Rollins, Somers, Thompson Falls, Winston, York.
New Mexico: Cimmaron.
Oregon: Ashwood, Burns, Corvallis (?), Eagle Point, Flora, Gibbon, O'Neil, Riverside, South Umpqua, Tiller, Umpqua, Viewpoint.
Texas: Fort Davis, Marathon.
Utah: Whiterocks.
Washington: Fruitland, Gray, Lakeside, Silcott, Stratford.
Wyoming: Jackson.

In general this species appears to be most abundant in the mountains or on more or less timbered uplands. As is shown in the list of localities, the tick has been collected from the extreme northern to the extreme southern part of the United States. It appears, however, to be much more numerous in the northern latitudes. It has been taken during our investigations at altitudes ranging from 227 feet to as high as 7000 feet above sea level.

Hosts.

Since this species does not drop from the host to moult, the animals upon which adults have been taken must be considered as hosts of the immature stages as well.

The host of the type specimens is the moose. The young moose from which the types were taken was reported to have been heavily infested. The elk or wapiti is also commonly attacked and the beaver has been recorded as a host. We have found the horse to be the preferred host among domestic animals but the ox is frequently infested.

In April 1910, Dr R. B. Hoag sent in a large number of ticks from elk (*Cervus canadensis*) taken at Aldridge, Montana. Mr D. C. Nowlin forwarded us specimens collected on elk cows and calves near Jackson, Wyoming, on April 30, 1912. He states that ticks are very abundant on the elk in that locality. On May 14, 1910, Mr C. Birdseye collected a single female attached to the anus of one of five mule deer (*Odocoileus hemionus*) killed near Darby, Montana. The mountain goat also acts as a host as shown by the fact that many adults and some nymphs (the nymphs were probably this species though not definitely determined) were taken on each of three goats killed on May 14, 1910, by Mr Birdseye, near Darby, Montana.

D. albipictus has been reared experimentally from larva to adult on the guinea-pig and tame rabbit, as well as on the ox and horse. A large number of attempts to feed the tick on guinea-pigs were made but only in one case did any female become sufficiently engorged to deposit eggs. In this experiment one female became $\frac{1}{4}$, and another $\frac{1}{3}$, engorged when dislodged by the host, which was collared in the usual manner employed in our tick work. When rabbits were used many ticks were shaken off but some appeared to drop off normally, although they were smaller than the average for dropped off ticks. On a number of occasions many larvae of this species were placed on sheep and goats. A few were found attached but were dead two days later, and hundreds died in the greasy wool without being able to reach the skin.

Seasonal History.

Our records indicate that this species is to be found on hosts only during the late fall, winter, and early spring. The earliest record which we have of the occurrence of ticks on a host is October 29. This lot was collected by Mr L. L. Stevens at Tiller, Oregon, and contained 1 ♂ (newly moulted), 17 nymphs (slightly to $\frac{4}{5}$ engorged), and two slightly engorged larvae. The stages present indicate that the first infestation had not been picked up by the hosts more than 20 days before. About November 10, 1912, a single female ($\frac{2}{3}$ engorged) was taken near Fort Davis, Texas (altitude 4927 feet). During the winter of 1911–12, Mr H. H. Hach made observations for us to determine the first and last occurrence of this tick. About November 15 small lesions were observed on horses, but no ticks were found until December 2, when 4 ♂ and 2 ♀ ($\frac{1}{20}$ to $\frac{1}{2}$ engorged) were collected. Ticks were found on horses throughout the winter, but during the first half of February they became much more numerous. This was during a warm period. The last specimens taken were collected on April 4. Examinations of hosts made on April 27 and subsequent dates failed to reveal the presence of any specimens of this species. No ticks were found on hosts in this locality on December 23, 1912, and during previous examinations in the fall, but on the next observation, which was made January 9, 1913, 3 ♂, 8 ♀ (mostly unengorged, one fully engorged), and 25 nymphs were found. Thus it would appear that in this locality few ticks got on the hosts during the winter of 1912–13 until about December 10.

The latest date on which we have a record of the collection of this tick is May 31. In this case a single, slightly engorged, female was taken on a horse at Pony, Montana, at an altitude of about 5500 feet. As previously stated, nymphs and adults were taken near Darby, Montana, on May 14, and a single female on May 19, 1910. These were all taken from hosts killed at between 5000 and 7000 feet altitude.

Nymphs are found on the hosts throughout practically the entire period when adults are present. Of course their appearance shortly precedes that of the adults and the latter are present some days after the last nymphs moult. March and April are the months when the ticks in both the nymphal and adult stages are usually most abundant.

At Dallas, Texas, larvae hatched from eggs deposited by females dropped from hosts in the winter and spring, exhibited a decided disinclination to attach themselves to hosts until the following fall and winter. In the northern part of the range of this tick the eggs have been found not to hatch until the late summer and early fall[1]. Hence we may conclude that in the warmer portions of the country where this tick occurs the larvae may hatch during the summer but remain inactive (as observed at Dallas) until cool weather. In the colder portions of its range the hatching does not take place (as observed by Mr W. V. King, in the Bitter Root Valley, Montana) until late summer or fall. In either case the larvae attach themselves to hosts when favourable weather prevails during the fall, winter or spring.

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[1] From a statement by Mr W. J. Hays (*Amer. Nat.* Vol. II. (x.), p. 559, 1868) we learn that ticks collected in New York City on April 13 began depositing eggs on May 1 and these eggs hatched on July 3. Dr Gordon Hewitt (*Rept. Dominion Ent.* for 1911, p. 225) states that egg laying began (presumably in Ottawa, Canada) at the end of April and hatching began early in July. Both of these records were probably made indoors although this point is not stated.

Life History.

As previously stated in the introductory remarks, this tick remains on the host for both moults.

Oviposition takes place in the usual manner in the most protected place available to the female after dropping off its host. The duration of the oviposition period varies greatly, according to the temperature, and, to some extent, the humidity, following the dropping of the engorged female. The shortest preoviposition period which we have observed at Dallas, Texas (see Tables I and III) was seven days, and the longest 134 days. The minimum record was made on a female collected in Montana on April 15, 1910, and received at Dallas, April 22, hence the temperature experienced by this tick during the first four days of its preoviposition period is not known.

The rate of oviposition fluctuates considerably with changes in temperature. The greatest number of eggs which we have observed to be deposited during a single day is 393. The period of egg laying varied from 19 to 42 days. The number of eggs deposited by a single female ranged from 1455 to 4411 in the nine counts made (see Table I). The last three records given in this table were made on ticks kept in an incubator at a mean temperature of about 90° F. The number of eggs deposited is usually in proportion to the size of the engorged tick. The length, width and thickness in millimetres of some of the ticks, the deposition of which is recorded in Table I, were as follows: No. 3, $11 \times 8{\cdot}1 \times 5{\cdot}1$; No. 4, $11{\cdot}5 \times 8{\cdot}5 \times 6{\cdot}1$; No. 7, $10{\cdot}6 \times 7{\cdot}9 \times 4{\cdot}8$; No. 8, $11{\cdot}4 \times 8{\cdot}5 \times 5{\cdot}1$; No. 9, $11{\cdot}2 \times 7{\cdot}9 \times 4{\cdot}6$. The length does not include the capitulum. The females die within one to 30 days after completing oviposition.

The eggs of this tick are slightly smaller than those of the other American species of this genus, the size ranging from 452 by 373 microns to 488 by 387 microns. They are smooth and shining, yellowish-brown in colour and ovoid in outline. They are coated with a moderate amount of the viscid secretion supplied by the *vesica biloba.*

At Dallas, Texas, the incubation period has been found to vary from 33 to 71 days. Most of our figures on this point are determined by computing the time from the beginning of deposition to the first hatching of larvae in the entire mass of eggs deposited by one female. All of the records given in Table II were made on ticks kept on moist sand in the laboratory. The length of the incubation period is closely related to the mean temperature during hatching. In the northern

TABLE I. *Oviposition of* Dermacentor albipictus.

Tick no.	Date female dropped	Preoviposition period (days)	Number of eggs deposited each day during deposition period																				
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1910 Mar. 23	18	*	110	187	275	393	239	*	*	355	97	186	238	227	91	*	67	84	88	105	64	39
2	Apr. 7	20	139	189	220	275	339	218	122	183	258	183	166	154	231	156	92	19	26	33	56	23	13
3	1911 Mar. 3	17	108	160	85	10	59	116	66	72	61	131	90	192	145	149	88	178	116	76	60	20	70
4	,, 3	27	4	120	137	160	137	100	166	137	112	45	83	114	170	231	123	*	47	53	130	132	97
5	1912 Jan. 8	94	80	113	170	152	207	46	*	189	183	226	131	101	169	228	200	176	156	67	62	112	128
6	,, 8	85	241	196	246	243	252	120	*	284	224	253	187	135	180	244	248	222	186	53	132	137	155
7	Nov. 29 ?	17 ?	289	*	554	357	200	216	146	62	*	103	40	18	10	6	4	*	12	*	3	0	0
8	,, 29 ?	17 ?	174	*	409	136	347	243	231	108	*	264	113	73	55	20	28	*	25	*	0	17	2
9	,, 29 ?	19 ?	40	126	132	137	238	158	*	348	117	79	52	23	2	*	3	Dead					

			22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	Total no. of eggs
1	1910 Mar. 23	18	42	19	0	0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2906
2	Apr. 7	20	0	3	7	5	0	0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3110
3	1911 Mar. 3	17	91	88	101	23	*	*	7	63	46	29	16	20	18	3	3	3	3	1	0	0	0	—	—	—	2564
4	,, 3	27	84	80	79	10	21	37	12	54	41	25	*	*	12	14	7	6	5	0	0	Dead					2785
5	1912 Jan. 8	94	65	77	59	35	22	18	22	13	3	*	11	1	0	2	0	6	6	0	0	2	1	0	0	Dead	3239
6	,, 8	85	75	96	59	49	49	39	31	23	13	11	4	1	2	10	3	4	4	0	0	0	0	0	0	Dead	4411
7	Nov. 29 ?	17 ?	0	0	0	Dead																					1920
8	,, 29 ?	17 ?	1	0	0	0	Dead																				2246
9	,, 29 ?	19 ?																									1455

* The eggs deposited on this day were counted with those on the subsequent day.

TABLE II. *Incubation of* Dermacentor albipictus *in the laboratory at Dallas, Texas.*

Oviposition began	Hatching began	Period of incubation	Temperature during incubation		
			maximum	minimum	daily mean
1910	1910	days	°F.	°F.	°F.
April 15	May 20	42	91·0	43·0	71·22
,, 20	June 4	45	100·0	43·0	74·34
,, 11	,, 1	51	97·0	43·0	72·56
,, 26	,, 7	42	100·0	58·5	76·20
,, 30	,, 10	41	100·0	59·0	76·88
May 23	,, 25	33	100·0	60·0	82·37
1911	1911				
Mar. 7	May 11	65	98·5	49·0	70·77
Feb. 16	April 20	63	98·5	32·0	66·12
Mar. 28	May 20	53	93·0	52·0	73·15
April 23	June 4	42	102·5	56·0	77·55
Mar. 31	May 25	55	94·0	56·0	72·70
,, 20	,, 17	58	93·0	52·0	69·57
April 29	June 9	41	102·5	56·0	79·91
1912	1912				
Feb. 27	May 8	71	88·5	35·0	67·34
Mar. 20	,, 13	54	88·5	39·0	74·69
,, 28	,, 17	50	88·5	48·5	71·35
April 4	,, 18	44	88·5	51·0	72·87
,, 12	,, 26	44	95·0	53·0	75·69
,, 16	,, 27	41	95·0	53·0	76·12
,, 25	June 4	40	96·0	60·0	78·94
,, 27	,, 1	35	96·0	60·0	78·60
May 3	,, 9	37	96·0	60·6	79·99

part of the range of this species, and in the higher altitudes the incubation period probably equals the longest period observed by us, and in many cases no doubt exceeds three months.

The Larva (Pl. XI, figs. 7, 9, 11): When first hatched the larvae are pale brownish-yellow; the bodies are plump and the actions very sluggish. Hatching proceeds in about the order in which the eggs are deposited and the larvae remain on or near the egg mass after they emerge. They soon become dark reddish-brown and often move a short distance from the egg mass where they settle down in a dense bunch and remain quiet for some time. At Dallas the majority of the larvae remain in such bunches on or near the soil surface throughout the summer months. They are not easily disturbed and when left untouched for a short time they soon form a bunch again. As the cooler autumn weather approaches they begin to scatter and crawl about.

TABLE III. *Preoviposition, incubation, larval longevity and total non-parasitic period of* Dermacentor albipictus.

Date females collected	Date oviposition began	Preoviposition period (days)	Date hatching began	Period from beginning deposition to first hatching (days)	Date last larva died	Larval longevity (days)	Period from dropping of female to death of last larva (days)
Mar. 28, 1910	Apr. 20, 1910	23	June 4, 1910	45	Mar. 23, 1911—Apr. 1, 1911	292–301	360–369
Apr. 1, ,,	,, 14, ,,	13	,, 4, ,,	51	Oct. 18, 1910—Nov. 25, 1910	136–174	200–238
,, 2, ,,	,, 26, ,,	24	,, 7, ,,	42	Feb. 1, 1911—Feb. 18, 1911	239–256	305–322
* ,, 12, ,,	,, 28, ,,	16	,, 6, ,,	39	,, 19, ,, —Mar. 11, ,,	258–278	313–333
,, 15, ,,	,, 22, ,,	7	,, 7, ,,	46	,, 19, ,, — ,, ,,	257–277	310–330
May 9, ,,	May 23, ,,	14	,, 25, ,,	33	,, 1, ,, —Feb. 18, ,,	221–238	268–285
Dec. 12, ,,	Mar. 11, 1911	89	May 17, 1911	67	Nov. 9, ,, —Dec. 28, ,,	176–225	332–381
,, 12, ,,	,, 11, ,,	89	,, 20, ,,	70	Jan. 5, 1912—Jan. 31, 1912	230–256	389–415
Jan. 15, 1911	,, 7, ,,	51	,, 11, ,,	65	,, 5, ,, — ,, ,,	239–265	355–381
Feb. 5, ,,	Feb. 16, ,,	11	Apr. 20, ,,	63	July 14, ,, —July 24, ,,	85–95	159–169
*Nov. 25, ,,	Apr. 7, 1912	134	May 18, 1912	41	Mar. 18, 1913—Apr. 26, 1913	304–343	479–518
* ,, 27, ,,	,, 1, ,,	126	,, 20, ,,	49	Dec. 28, 1912—Jan. 31, ,,	222–256	397–431
Dec. 15, ,,	Feb. 27, ,,	74	,, 8, ,,	71	Feb. 17, 1913—Feb. 28, ,,	285–296	430–441
*Jan. 17, 1912	Apr. 12, ,,	86	,, 19, ,,	37	Dec. 28, 1912—Jan. 31, ,,	346–380	469–503

* These females dropped off normally from the host, the others were picked off.

In the Northern States where hatching does not take place until late summer or early fall, this resting period must be relatively shorter, at least for some individuals, as they begin infesting hosts in the late fall. This clustering habit is evidently of great value in protecting the larvae from the drying effects of the hot summer weather and the inactivity preserves their vitality. As previously stated, the larvae do not readily attach themselves to hosts when applied during their resting period in hot weather, and few of those which do attach themselves become engorged.

TABLE IV. *Moulting of larvae of* Dermacentor albipictus *when detached from host (ox).*

Date engorged larvae detached	No.	Dates of moulting		Moulting period (days)	No. moulted
		first moulted	last moulted		
1909		1909			
Oct. 11	2	Oct. 23	—	12	1
,, 14	2	,, 20	—	6	1
,, 15	1	,, 26	—	11	1
,, 16	1	,, 27	—	11	1
,, 20	2	,, 27	Nov. 11	7–22	2
,, 30	1	Nov. 27	—	28	1
		1910	1910		
Nov. 22	2	Jan. 11	June 15	50–54	2
,, 23	2	,, 24	—	62	1
,, 25	2	,, 11	—	47	2
		1909			
Nov. 26	3	Dec. 7	Jan. 26	11–61	3
,, 27	13	,, 7	Feb. 20	10–82	11
,, 29	9	,, 7	,, 8	8–71	6
,, 30	7	,, 7	,, 15	7–77	6
Dec. 2	3	,, 31	Jan. 20	29–49	3
1910		1910			
Jan. 27	3	Mar. 7	Mar. 9	39–41	2
,, 29	1	,, 4	—	34	1
Feb. 25	2	,, 22	—	25	1
Mar. 1	1	,, 22	—	21	1
Totals	57				46

The longevity of the larvae of this species has been found to range from 60 to at least 346 days. Large masses of larvae left undisturbed on fairly moist sand showed the maximum longevity.

When applied to a host some of the larvae attach themselves immediately while others fall off and may not secure an attachment for several days. The larvae are elongate oval in form and slate coloured when engorged (Pl. XI, fig. 9). The size ranges from 1·0 mm. in length (including capitulum) by 0·7 mm. wide, by 0·5 mm. thick to 2·0 × 1·0 × 0·7 mm. The larvae, as well as all other stages of this species, are very easily detached from the host. This is particularly true of specimens in the quiescent period prior to moulting. In our experiments many engorged larvae were found detached, and moulting records were kept of a number of these which were placed on moist sand. Since many larvae must be rubbed or shaken off in nature, moult off the host and again become attached, we have given in Table IV some records on this point to show the range in the moulting period under such conditions. The temperature has much influence on the time required for this moult as also the amount of moisture present. It is thought, however, that the state of development prior to becoming detached from the host is of still greater importance in considering this period.

The shortest period observed by us from the application of the larvae to the first moult was nine days. Some larvae moult as late as 20 days after being applied to the host (see Table VI).

There is a high mortality among the larvae of this species after they find hosts. Dead larvae have been observed in all stages of engorgement either attached to the skin or hanging in the hair of the host.

The Nymph (Pl. XI, figs. 8, 10): The longevity of nymphs, which moulted from individuals detached from hosts as engorged larvae, has been found to vary from two to 77 days. In these tests the nymphs were kept on moist sand in the laboratory at Dallas, Texas.

When moulting takes place on the host in the normal manner, the nymph crawls backward or sideways out of the larval skin and attaches itself to the host near the point of larval attachment. The larval skin usually remains attached to the host for some time. Immediately after moulting, the legs, mouth-parts and anterior part of the scutum are pale yellow and translucent. The posterior part of the scutum is darker and the remainder of the body is pale yellowish-brown. The body is elongate. Nymphs have been observed to become detached, crawl about, and reattach themselves several times before they become noticeably engorged. While engorging, the nymphs retain the elongate form and become light bluish-gray in colour, although some are yellowish and translucent, due probably to the character of the food.

The size of engorged nymphs has been found to vary from 5·4 mm. in length (including the capitulum), by 3·9 mm. in width, by 1·5 mm. in thickness, to 2·8 by 1·7 by 0·9 mm. Some individuals have been found to attain a thickness of 1·9 mm. The thickness decreases somewhat as the development of the adult within the nymphal skin progresses.

The shortest period between the moulting of larvae and moulting of nymphs noted by us was six days. We are inclined to think that some nymphs began moulting a day or more before being observed in the two cases where the duration of the nymphal stage was six days. The usual period, from the moulting of larvae to the moulting of nymphs, appears to be 9–12 days (see Table VI).

Nymphs, which moulted from larvae detached from a host, attached themselves again when given an opportunity. Several nymphs which had moulted off a host were put on an ox on January 24, 1910. About half of these died without becoming attached while the others became attached, and on February 1 one fully engorged specimen was found detached. Another was detached on February 9 and a third on February 14. The last individual remained on the host until March 4 when it was found detached and apparently fully engorged. In this instance the last nymph had been on the host for 39 days. In another case a nymph put on an ox March 11, 1910, was fully engorged on March 23.

As previously mentioned, the nymphs are easily detached, especially when engorged, and this often happens in nature. Although some of them are held on the host by the long winter coat of the animal, many undoubtedly fall to the ground and moult to adults, some of which again find hosts. Table V shows the range in the moulting period of nymphs detached from the host and kept upon moist sand in the laboratory at Dallas, Texas. In this case, as in the moulting of the larvae, the temperature and state of development of the ticks at the time of detachment are the most important factors governing the moulting period. Nymphs approximately one-half engorged, have been found to moult when removed from a host, but individuals less than one-half engorged invariably die.

The Adult (Pl. X, figs. 5, 6; Pl. XI, figs. 1–6): Since this species normally remains on the host to moult, the longevity of unattached adults is of much less practical importance than it is with species which drop off their host before moulting. However, engorged nymphs, as well as adults, are often detached by the host. We have found also that adults will reattach themselves to hosts even though they are one-fifth engorged. These facts increase the importance of a knowledge of the longevity of adults moulted from nymphs previously removed from a host, as well as the longevity of specimens detached in the adult

TABLE V. *Moulting of nymphs of* Dermacentor albipictus *when removed from host.*

Date nymphs collected	Host	State of engorgement	No. collected	Dates of moulting		Range in moulting period	Number moulted		
				first moulted	last moulted		males	females	total
1910				1910	1910				
Mar. 23	Horse	Fully	1	Apr. 5	—	13	0	1	1
,, 28	,,	,,	1	,, 12	—	15	0	1	1
Apr. 19	,,	,,	1	May 1	—	12	0	1	1
Oct. 29	,,	1/3 to 4/5	11	Nov. 26	Dec. 10	28–42	1	4	5
				1911	1911				
Dec. 24	,,	4/5 to fully	3	Feb. 1	Feb. 17	39–55	3	0	3
,, 26	,,	1/2 to fully	6	Jan. 12	,, 21	17–57	0	2	2
1911									
Jan. 7, 8	,,	1/5 to fully	40	Feb. 17	Mar. 25	41–76	12	16	28
,, 10	,,	4/5 to fully	12	,, 3	,, 27	24–76	2	10	12
Feb. 3	,,	1/2 to fully	23	,, 15	Apr. 2	12–58	7	12	19
,, 5	,,	4/5 to fully	88	,, 15	Mar. 30	10–53	18	64	82
May 16	Guinea-pig	3/4	1	June 6	—	21	0	1	1
					1912				
Nov. 11	Ox	2/3 to 3/4	2	Dec. 24	Jan. 8	43–58	1	1	2
1912				1912					
Jan. 11	Horse	1/2 to fully	7	Feb. 19	Mar. 25	39–74	0	4	4
,, 25	,,	1/2 to fully	7	,, 19	Apr. 5	25–71	2	3	5
Mar. 23	,,	Fully	2	Apr. 14	—	22	0	1	1
Totals			205				46	121	167

stage. A large number of records made on these points at Dallas, Texas, show that adults which have never fed live from a few days to 140 days, individuals which have fed after moulting but have not become perceptibly engorged may live for 182 days, and females partially engorged, but not sufficiently so to oviposit, may live for 129 days. The males are shorter lived than the females, the greatest longevity observed being 97 days. The longevity of males on the host (together with females) is rather less than when they are removed. In our experiments the longest period from the moulting of the first male on a host to the death of the last male was about three months.

The first ticks to reach the adult stage on a host are usually males. The females begin emerging from a few hours to a day later. There seems to be a slightly larger number of females than males, this being especially notable in ticks which moult to the adult stage off the host. As shown in Table V, the proportion of males to females is about 1 to 3.

The emergence of the adults from the nymphal exuviae is very similar to that observed in the first moult. The exuviae often remain attached to the host for some time. The adults, after freeing themselves from the nymphal skin, usually crawl some distance before becoming reattached. They have been seen to detach themselves and crawl about a number of times before they settle down for engorgement.

When newly emerged the adults are soft and pale, the white markings being indistinct, and the actions of the tick are awkward. The size of the adults varies considerably, dependent, in part at least, on the food supply of the nymphs. One of the largest males we have seen measured 5·9 mm. in length (including capitulum), by 4·5 mm. in width, by 1·2 mm. in thickness.

One female, in a lot of ticks collected as unengorged adults in Oregon and placed on an ox March 29, 1910, at Dallas, Texas, dropped off its host fully engorged on April 7, or the ninth day after attachment. Other adults placed on hosts under similar circumstances were only partially engorged after being attached for much longer periods. Females which became adult on hosts were observed to engorge and drop off on the eighth day after reaching the adult stage (see Table VI). The maximum time required for engorgement is difficult to determine, due to the successive moulting of nymphs to adults. The longest time a female has been observed to remain on a host was 30 days. The bodies of the males become considerably thickened during feeding, and they, as well as the females, exude numerous drops of excrement as long as they remain on the host.

The engorged females (Pl. XI, figs. 5, 6) usually have a distinct olive-green tint dorsally and are more slate coloured ventrally. The size varies considerably. The ticks engorged experimentally on small mammals are usually smaller than those from horses and cattle. Fully engorged specimens range in size from 8·9 mm. in length (including capitulum), by 6·3 mm. in width, by 3·9 mm. in thickness, to 13·8 by 9 by 5·2 mm.

Pairing of the sexes begins from the fourth to the thirteenth day after the first adults appear. The male seeks the female and crawls beneath her so that their venters are in apposition. During copulation the legs of the male closely clasp the body of the female. Sometimes another male attempts to displace the male in this position, whereupon he sets up a vigorous seesawing with his hind legs across the abdomen of the female which prevents displacement by the attacking male. The mouth-parts of the male are inserted into the genital orifice of the female and when they are withdrawn the male deposits a spermatophore, the neck of which is inserted into the female orifice[1]. It appears that the spermatic fluid is then pressed out by the male. After the act the male usually attaches itself to the host beneath the female. The entire act consumes less than 50 minutes though the exact time has not been determined. A female has been observed to copulate at least three times, and males may copulate two or more times.

The spermatophores (Pl. X, fig. 7) obtained have been partially or wholly collapsed, hence their original shape could not be definitely made out. They appear to be almost globular with a neck which is broadest at its base. When collapsed they are deeply concave on the side next to the female and the neck appears to be grooved along one side. The tip of the neck is curved toward, and inserted into, the vulva. The size of the three collapsed spermatophores measured was 889 microns, 918 microns, and 932 microns in length (including neck), and 531 microns, 646 microns, and 617 microns in width, respectively; the neck measured about 287 microns in length. The spermatophore becomes cemented to the body of the tick by a substance exuded by the male, which hardens when dry. After copulation the body of the spermatophore lies just posterior of the genital opening with the neck extending anteriorly to the opening into which the tip is inserted.

The males move about considerably, especially after most of the engorged females have dropped off. Sometimes several males are found attached close to a single female at the same time. The females copulate at any stages of their engorgement on and after the fourth day following moulting.

Summary of the non-parasitic period. As previously stated, the preoviposition period ranges from 7 to 134 days, the incubation period from 33 to 71 days, and the larval longevity from 50 to at least 346 days. The combined periods from the dropping off of the engorged females to the death of the last larva, or the non-parasitic period, range normally from 159 to at least 479 days. Table III gives a summary of this data.

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[1] Compare with the observations of Nuttall and Merriman (III. 1911) *Parasitology*, IV. 39–44, Fig. 1.

TABLE VI. *The parasitic period of development of* Dermacentor albipictus.

1910	Infestation No. 1. On rabbit.
Oct. 18.	About 200 larvae put on head of rabbit.
,, 19 (1st day).	About 100 appeared to be attached.
,, 31 (13th day).	2 at least engorged or nearly so.
Nov. 5 (18th day).	Larvae began moulting.
,, 11 (24th day).	A nymph appears fully engorged.
,, 17 (30th day).	The above nymph moulted to a female.
,, 19 (32nd day).	Female crawling on host and shaken off several times. Removed from host.
,, 23 (36th day).	Another nymph moulted to a female.
,, 27 (40th day).	Female lost.
Dec. 11 (54th day).	Another nymph moulted to a female.
,, 19 (62nd day).	Female lost. No other ticks found.
1911	Infestation No. 2. On guinea-pig.
Apr. 26	About 100 larvae put on guinea-pig.
,, 27 (1st day).	Many larvae attached.
May 5 (9th day).	1 larva appears fully engorged.
,, 9 (13th day).	Above larva moulted to a nymph.
,, 20 (24th day).	First nymph moulted (♂).
,, 27 (31st day).	Male scratched off by host. No other ticks found.
1911	Infestation No. 3. On rabbit.
Mar. 15, 4.45 p.m.	75 larvae put on rabbit.
,, 15, 6 p.m.	7 or 8 attached. A few crawling.
,, 15, 9.30 p.m.	20 or 30 attached.
,, 17 (2nd day).	At least 6 attached.
,, 27 (12th day).	2 larvae fully engorged.
Apr. 1 (17th day).	1 moulted to a nymph.
,, 2 (18th day).	Another moulted to a nymph.
,, 3 (19th day).	Smaller nymph scratched loose, later reattached.
,, 5 (21st day).	1 nymph is fully engorged. Other not found.
,, 10 (26th day).	Nymph moulted to a female. No other ticks found. Female removed.
1911	Infestation No. 4. On guinea-pig.
Oct. 24, 3.15 p.m.	75 to 100 larvae placed on guinea-pig.
Nov. 1 (8th day).	Some larvae appeared fully engorged.
,, 6 (13th day).	Larvae began moulting.
,, 11 (18th day).	3 nymphs appeared engorged.
,, 15 (22nd day).	First nymph moulted (♀). Last larva moulted.
,, 20 (27th day).	7 males, 7 females and 2 nymphs found. First copulation observed.
Dec. 1 (38th day).	6 females (slightly to $\frac{1}{3}$ engorged) scratched off the host. 5 males attached.
,, 2 (39th day).	5 females (slightly to $\frac{1}{3}$ engorged) off the host.
,, 7 (44th day).	Only 1 male found.
,, 9 (46th day).	2 males scratched off by the host. No other ticks found.

TABLE VI (*continued*).

1911	Infestation No. 5. On bovine.
Oct. 25.	About 1500 larvae put on shoulders and neck of bull.
Nov. 8 (14th day).	5 nymphs recently moulted.
,, 11 (17th day).	Several nymphs fully engorged and quiescent.
,, 14 (20th day).	First nymphs moulted to adults (7 ♂ s, 2 ♀ s).
,, 18 (24th day).	All nymphs appeared to have moulted.
,, 20 (26th day).	First copulation observed.
,, 23 (29th day).	1 engorged female dropped off.
,, 24 (30th day).	1 female dropped off.
,, 25 (31st day).	8 females dropped off or crushed.
,, 26 (32nd day).	2 females dropped off.
,, 27 (33rd day).	2 females dropped off.
Dec. 2 (38th day).	1 female dropped off.
,, 4 (40th day).	1 female. No other females found.
,, 23 (59th day).	6 males attached. These removed and no other ticks found.
1911	Infestation No. 6. On bovine.
Nov. 11	About 700 larvae put on calf (Jersey bull).
,, 21 (10th day).	1 larva fully engorged.
Dec. 7 (26th day).	1 male and 1 female recently moulted.
,, 16 (35th day).	1 female about $\frac{1}{10}$ engorged. To date only 2 males observed on host. These have now disappeared. A male from another host placed with above female.
,, 18 (37th day).	Female dropped. Another female about $\frac{1}{20}$ engorged.
,, 20 (39th day).	A male placed with this female.
,, 23 (42nd day).	This female dropped off. No others found.
1911	Infestation No. 7. On rabbit.
Nov. 22.	100 to 200 larvae put on rabbit.
,, 28 (6th day).	1 larva appears fully engorged.
Dec. 2 (10th day).	1 larva moulted.
,, 4 (12th day).	Collar off host; 4 larvae and 18 nymphs became detached.
,, 7 (15th day).	Last larva moulted.
,, 8 (16th day).	At least 2 nymphs fully engorged.
,, 11 (19th day).	Nymphs began moulting (2 ♂ s).
,, 12 (20th day).	The first female appeared (3 ♂ s and 2 ♀ s present).
,, 16 (24th day).	10 males and 5 females present. First copulation observed. 2 females scratched off.
,, 19 (27th day).	First female dropped off.
,, 21 (29th day).	Last nymph moulted. 2 females dropped off.
,, 22 (30th day).	Only 1 male on host. 4 others transferred from another host. 2 females dropped off.
,, 23 (31st day).	1 female dropped off.
,, 24 (32nd day).	2 females dropped off.
1912	
Jan. 1 (40th day).	2 females dropped off.
,, 3 (42nd day).	1 female ($\frac{1}{8}$ engorged) scratched off. 2 others present ($\frac{1}{12}$ and $\frac{1}{20}$ engorged).
,, 9 (48th day).	1 female ($\frac{1}{7}$ engorged) scratched off.
Mar. 8 (107th day).	Last tick (a female $\frac{1}{15}$ engorged) scratched off by host.

TABLE VI (*continued*).

1911	Infestation No. 8. On bovine.
Dec. 1.	About 900 larvae put on calf (Jersey bull).
,, 16 (15th day).	20 nymphs found. Moulting probably began six or seven days ago.
,, 20 (19th day).	Nymphs began moulting (6 ♂s, 3 ♀s).
,, 24 (23rd day).	Last nymph moulted (♀). First copulation observed.
Jan. 8 (38th day).	Last date on which a tick was observed on host (1 ♀, $\frac{1}{25}$ engorged). None of the females became fully engorged but were dislodged or dropped off before reaching repletion.
1911	Infestation No. 9. On bovine.
Dec. 1.	About 700 larvae put on white bull.
,, 16 (15th day).	6 nymphs present. Moulting probably began three or four days previously.
,, 24 (23rd day).	First nymph moulted (♂).
,, 26 (25th day).	First female appeared.
1912	
Jan. 6 (36th day).	Last nymph moulted.
,, 7 (37th day).	First copulation observed. The first engorged female dropped off.
,, 9 (39th day).	5 females dropped off to date. The rest of the females smaller.
,, 13 (43rd day).	1 female dropped off.
,, 17 (47th day).	1 female dropped off.
,, 19 (49th day).	1 female dropped off.
,, 20 (50th day).	1 female dropped off.
,, 21 (51st day).	2 females dropped off.
,, 22 (52nd day).	1 female dropped off.
,, 24 (54th day).	2 females dropped off.
,, 28 (58th day).	2 females dropped off. No other ticks found.
1912	Infestation No. 10. On bovine.
Nov. 23.	About 800 larvae put on white bull.
,, 29 (6th day).	Some larvae fully engorged.
Dec. 1 (8th day).	Larvae began moulting.
,, 6 (13th day).	Some nymphs fully engorged. At least 61 nymphs present.
,, 13 (20th day).	Nymphs began moulting (7 ♂s and 1 ♀).
,, 17 (24th day).	Mating has begun since yesterday.
,, 21 (28th day).	Last nymph moulted. First engorged female dropped off.
1913	
Jan. 3 (41st day).	Last engorged female dropped off.
,, 15 (53rd day).	8 males still present on host.
1913	Infestation No. 11. On horse.
Feb. 24	About 800 larvae put on horse.
Mar. 4 (8th day).	A few larvae found fully engorged.
,, 7 (11th day).	Larvae began moulting.
,, 13 (17th day).	Some nymphs almost replete.
,, 17 (21st day).	Nymphs began moulting (♂).
,, 18 (22nd day).	3 males and 1 female found, all on neck.

TABLE VI (*continued*).

Mar. 25 (29th day).	Last nymph moulted.
,, 26 (30th day).	First mating observed (1 pair).
,, 27 (31st day).	Several pairs noted, spermatophore found.
,, 30 (34th day).	First engorged female dropped off.
,, 31 (35th day).	At least 17 engorged females dropped off.
Apr. 1 (36th day).	At least 4 dropped off.
,, 2 (37th day).	8 dropped off.
,, 3 (38th day).	5 dropped off.
,, 4 (39th day).	At least 4 dropped off.
,, 7 (42nd day).	1 dropped off.
,, 8 (43rd day).	1 dropped off.
,, 10 (45th day).	1 female (½ engorged) dropped off during examination. No other females found.
,, 14 (49th day).	A total of 24 males present.
,, 22 (57th day).	A few males attached. Host has been rubbing ticks off.
,, 25 (60th day).	No more ticks found.
1913	Infestation No. 12. On bovine.
Feb. 25	About 1000 larvae put on bull.
Mar. 4 (7th day).	Very few larvae found. None as large as on horse.
,, 8 (11th day).	1 larva moulted (dead).
,, 19 (22nd day).	First nymph moulted (♂).
,, 22 (25th day).	A few of both sexes found. Infestation very light as compared with horse (Infestation No. 11).
,, 24 (27th day).	1 nymph found.
,, 26 (29th day).	No ticks found.
Apr. 1 (35th day).	No ticks observed since last date.
,, 2 (36th day).	1 unengorged female found.
,, 5 (39th day).	Female gone; no other ticks seen.
,, 14 (48th day).	1 male found.
,, 16 (50th day).	No ticks found on date nor subsequently.

Economic Importance.

D. albipictus has been considered of little or no economic importance until very recently. During these investigations we have found the tick to be an important pest of horses and cattle during the autumn, winter, and early spring. The tick is much more severe on horses than cattle, mainly owing to the preference shown for the former animal as a host. Reports have been received from California, Montana, and Oregon stating that horses and colts become very weak and that colts not infrequently succumb if the ticks are not promptly killed. During the spring, in territory infested by the Rocky Mountain spotted fever tick (*Dermacentor venustus*), the combined attack of these two species, together with a shortage of feed, often causes the death of numbers of horses where they are not properly cared for.

The moose and elk, as is well known, are often heavily infested with this tick. Mr D. C. Nowlin forwarded us specimens collected on elk cows and calves near Jackson, Wyoming, April 30, 1912. He states that the ticks are very troublesome in that locality in the spring and early summer, and that he is quite sure that a percentage of loss each season is due to this tick, as the parasites are to be found on the elk in sufficient numbers to sap the vitality out of any animal. Numerous other reports have come to our attention of elk being found in a dying condition, heavily infested with this tick, leading us to believe that the pest must be considered in the rearing and protection of this animal.

When the ticks are not numerous they occur mostly along the belly and between the legs. If numerous they are to be found on nearly all parts of the host. In our experiments with cattle, the ticks became attached in numbers on the neck and along the back, particularly above the shoulders and near the base of the tail.

One of our correspondents in Oregon, Mr H. H. Hach, who has made many interesting observations on this tick, states that he has observed a great difference in the susceptibility to attack of different horses even when kept under identical conditions. Often one horse in a herd of 20 or 30 was seen to be literally covered with ticks while the others were very lightly or entirely uninfested. Three of our bovine hosts used in experiments showed such a tendency to immunity. As stated in Table VI (Infestation No. 8), no females became engorged on a Jersey calf used as a host in comparison with a bull (Infestation No. 9). This calf, as well as two other animals, was tested several times with infestations of *D. albipictus* without a single specimen developing to repletion. It should be mentioned that these hosts showed marked resistance to the attack of other species of ticks. This resistance appears to be due largely to an unusually strong tendency to form scabs at the point of attack, thus healing the wound and throwing off the tick with the scab. On all hosts scabs are usually produced as a result of the insertion of the mouth-parts of the ticks. When the larvae first become attached a translucent yellowish exudate is thrown out at the point of attack. The subject of resistance will be discussed at greater length in another publication.

Dermacentor nigrolineatus[1] Packard.

Distribution. (Fig. 1.)

Comparatively little is known regarding the distribution of this species. The type is from the Adirondack Mountains in New York. Banks[2] states that specimens are in the New York State collection which probably came from the Adirondack Mountains; he also records the species from the Catskill Mountains in New York and from Vilas County, Wisconsin. Stiles[3] mentions a collection from Davidson county, Tennessee, and another from a host which came from Oklahoma. During the recent investigations of the Bureau of Entomology several specimens have been obtained from Laredo, Texas, a few from Kerrville, Texas, and many in all stages of development from Lake, Fentress County, Tennessee. The elevation of these localities ranges from 438 to 1700 feet. In each section there is a considerable area of hilly country and some woods or shrubbery.

Hosts.

The type specimens were taken from deer and most of the other collections have come from that host. Stiles[4] records females and nymphs from horses. A collection, which contained both males and females, was made by Mr Rumsey at Laredo, Texas, on deer (*Odocoileus virginianus texanus*), and two lots have since been taken on the same host by the late F. C. Pratt, at Kerrville, Texas. One of these contained two well engorged nymphs[5] and the other a single female ($\frac{1}{10}$ engorged). We have collected all stages on cattle at Lake, Tennessee, and have reared the species experimentally on that host. A few tests of the guinea-pig as a host were unsuccessful. Adults attached themselves to tame rabbits and fed, but none of them became engorged, the females probably being scratched off. A slightly engorged female placed in the ear of a dog became attached, but later disappeared.

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[1] The "red-brown winter tick" is suggested as a common name for this species on account of its colour and habit of feeding largely during the winter season.

[2] "A revision of the Ixodoidea of the United States." *Bur. of Ent., U.S. Dept. Agr., Tech. Ser.*, 1908, *Bull.* 15, p. 49.

[3] "The taxonomic value of the microscopic structure of the stigmal plates in the tick genus *Dermacentor*." *Pub. Health and Mar. Hosp. Service, Hygienic Lab.*, 1910, *Bull.* 62, pp. 54, 55.

[4] See reference cited in preceding paragraph.

[5] This material was considered to be *D. nitens* by Hooker, Bishopp and Wood (*Bur. of Ent., U.S. Dept. Agr.*, 1912, *Bull.* 106, p. 198). Recent studies of the immature stages show this to be an error.

Seasonal History.

Like its nearest relative, *Dermacentor albipictus,* this species usually feeds only during the autumn, winter and spring. The collection of the Bureau of Animal Industry contains two lots of this tick taken from hosts in January 1906. Mr Nathan Banks' collection contains specimens collected in June. This is the latest seasonal record of its occurrence on a host. During these investigations we have obtained nymphs on March 24, 1906, males and females on December 17, 1907, a female ($\frac{1}{10}$ engorged) on February 4, 1910, males and females (slightly to $\frac{2}{3}$ engorged) on November 25, 1910, males, females (unengorged to fully engorged) on November 14–16, 1911, and all stages on December 5–6, 1911.

Life History and Habits.

Dermacentor nigrolineatus passes through both moults on the host.

Oviposition: The preoviposition period as observed by us ranges from 122 to 161 days (see Table VIII). These records are based on ticks kept in the laboratory on moist sand at temperatures slightly above those out of doors. The rate of oviposition closely follows the mean daily temperature. The greatest number of eggs deposited during a 24-hour period was 223, and the greatest total number deposited by a single female was 2848. The eggs of three ticks were counted daily. The first of these ticks measured 10·9 mm. in length (including capitulum), by 8·0 mm. in width, by 5·2 mm. in thickness. This female was removed from a host on November 14, 1911, and began depositing on April 1, 1912, or 139 days after collection. On the first and subsequent days the following numbers of eggs were deposited: 20, 3, 26, 50, 89, 145, 71 (2 days), 60, 82, 129, 179, 170, 132, 146, 137, 49, 103 (2 days), 101, 161, 51, 79, 69, 123, 100, 95, 68, 40, 0, 81, 58, 20, 30, 19, 19, a total of 2705 eggs being deposited during a period of 36 days. Another female which was removed from a host on November 14, 1911, began ovipositing on April 11, 1912, or 149 days after collection. This tick measured 10·3 × 7·9 × 5·0 mm. The following numbers of eggs were deposited on the first and subsequent days: 46, 77, 171, 162, 223, 137, 84, 219 (2 days), 219, 216, 132, 99, 147, 204, 153, 156, 80, 45, 56, 50, 49, 26, 30, 21, 13, 17, 3, 11, 2, a total of 2848 eggs being deposited during this period of 30 days. A third tick which measured 8·6 × 7·5 × 4·2 mm. when it dropped off the host on December

11, 1911, began ovipositing on April 11, 1912, or 123 days after dropping off. Only 917 eggs were deposited by this female and oviposition continued 20 days. On the first and second days 106 eggs were laid and oviposition proceeded as follows on subsequent days: 10, 88, 34, 46, 24, 86 (2 days), 76, 75, 36, 58, 34, 79, 56, 48, 30, 11, 20. In each case the females died within a few days after oviposition was complete.

Counts were made daily of the eggs deposited by three other females. The first of these dropped off (fully engorged) a bovine host on November 1, 1912, began depositing April 8, 1913, or 158 days after dropping off, and deposited until May 18, or 41 days. During this period 2099 eggs were deposited. The second female dropped off a bovine host on November 4, 1912, and began depositing on March 31, 1913, or 116 days after dropping off its host and deposited 1914 eggs during the succeeding 49 days. The third individual dropped off a bovine host November 9, 1912, began depositing April 1, 1913, and deposited 2054 eggs during a period of 49 days.

The Eggs are oval in shape and yellowish-brown in colour. For some time before hatching, the legs and other structures can be clearly made out through the shell. As with other Ixodid ticks, the length of the incubation period depends on the temperature and humidity. The percentage of hatching is usually much higher in large, than in small masses of eggs.

As shown in Table VII, the incubation period varied from 37 to 55 days when the eggs were kept in the laboratory.

TABLE VII. *Incubation of* Dermacentor nigrolineatus *in the laboratory at Dallas, Texas.*

				Temperature during incubation		
Eggs deposited	Number of eggs	Hatching began	Incubation period	max.	min.	average daily mean
1912		1912	(days)	° F.	° F.	° F.
April 1	2700	May 26	55	95·0	48·5	73·7
,, 11	2800	,, 29	48	96·0	53·0	76·3
,, 11	122	,, 30	49	96·0	53·0	76·5
,, 14	132	,, 30	46	96·0	53·0	76·6
,, 14	162	,, 30	46	96·0	53·0	76·6
,, 22		,, 30	49	96·0	58·0	76·0
,, 23	500	,, 30	37	96·0	59·5	78·2

The Larva (Pl. XII, figs. 1–2): When first hatched the larvae are pale and sluggish. As they harden they become brownish-yellow and move about, but soon settle down in masses and remain quiet for long periods. The larvae which we have observed were hatched in spring and they remained practically motionless, unless disturbed, until towards the fall. No attempts were made to attach larvae to hosts during the summer, but it is our opinion, from the actions of the unfed larvae, that they would not attach themselves readily to hosts until autumn. This is also borne out by the fact that ticks of this species have not been collected on hosts during midsummer or early autumn.

As is shown in Table VIII the greatest longevity of larvae noted by us was 166 days. Larvae are capable, no doubt, of living much longer than this.

TABLE VIII. *Preoviposition, incubation, larval longevity and total non-parasitic period of* Dermacentor nigrolineatus.

Date females collected	Date oviposition began	Preoviposition period	Date hatching began	Period from beginning deposition to first hatching	Date last larva died	Larval longevity	Period from dropping of female to death of last larvae
1911	1912		1912		1912	(days)	(days)
Nov. 14	Apr. 1	139	May 26	55	Oct. 7, 100 alive	134+	328+
,, 14	,, 11	149	,, 29	48	Nov. 8, 150 alive	163+	360+
,, 14	,, 23	161	,, 30	37	Oct. 1—Oct. 28	124—151	322—349
Dec. 5	,, 22	139	June 4	43	Oct. 30	148	330
,, 11	,, 11	122	May 30	49	Aug. 10	72	243
—	,, 14	—	,, 30	46	Nov. 12	166	—
—	,, 14	—	,, 30	46	Oct. 1	124	—

We have found that engorged larvae removed from a host will moult to nymphs which are capable of becoming reattached to a host. In one instance a larva moulted on the fifth day after it was removed. The length of the moulting period of larvae detached from a host is dependent largely upon their state of development before removal.

The period from the attachment of larvae to the beginning of moulting (on the host) is about 10 days (see Table X).

The Nymph (Pl. X, figs. 10, 11): After the nymphs escape from the larval skins they attach themselves near by. The larval exuviae usually remain attached to the host by the mouth-parts for some time. The nymphs are pale yellowish-brown for a period after transformation, and are comparatively slow and clumsy in their motions. Fully engorged nymphs vary from almost white to slate-coloured. The body is elliptical in outline, but sometimes it is broadest at the anterior end. The length (including palpi), width and thickness of the average sized engorged nymph are about 2·3, 1·7 and 1·0 mm., respectively.

A nymph which moulted from an engorged larva collected on a cow in Tennessee readily attached itself to a calf at Dallas, Texas, when applied on December 11, 1911. On December 18 it was fully engorged but became detached during an examination made on December 19. The nymphs, as well as the larvae, are easily loosened from the host, especially during the quiescent period prior to moulting.

TABLE IX. *Moulting of nymphs of* Dermacentor nigrolineatus *when removed from bovine hosts.*

Date nymphs collected	State of engorgement	No. collected	Dates of moulting		Range in moulting period	Number moulted		
			first moulted	last moulted		males	females	total
1911			1911	1912	(days)			
Nov. 14	1/2 to fully engorged	20	Nov. 23	Jan. 19	9–66	10	5	15
Dec. 5	1/2 to fully engorged	8	Dec. 27	Feb. 1	22–58	1	6	7
,, 6	2/3 to fully engorged	11	,, 11	,, 14	5–70	2	9	11
Totals		39				13	20	33

Ticks which moulted from the larval stage on the host began to transform to adults about eight days later (see Table X). Some nymphs, apparently not more than one half engorged when removed from hosts, moulted to adults. The removal of the engorged ticks from the host greatly delays moulting. The longest period from collection to moulting in the lots observed was 70 days (see Table IX).

The Adult (Pl. X, figs. 8, 9; Pl. XII, figs. 3–8): Immediately after moulting to adults, the colour of the extremities of both sexes is a translucent brownish-yellow, the bodies being darker; the caecal system is visible through the integument as dark bands. The specific name is based on the appearance produced by these bands.

The engorged females are smaller than most Dermacentors. The length (including capitulum), width, and thickness, range from 8·6 × 5·7 × 4·2 mm. to 10·9 × 8·0 × 5·2 mm., respectively. The colour of the body varies from pale bluish-gray to rather dark bluish-gray with an olive tinge on the dorsum.

There appear to be rather more males than females, judging from observations of the tick on hosts and of specimens moulting off hosts (see Table IX).

A number of records have been kept of the longevity of adults maintained on moist sand in the laboratory. Unfed males lived from a few days to 95 days. Some unfed females lived for 69 days and one became attached to a host 66 days after moulting to an adult. A slightly engorged female in a lot of three females collected December 6, 1911, lived 209 days.

Individuals which became adult away from their hosts readily attached themselves to a calf and a rabbit. One female had become about ⅓ engorged on the ninth day after attachment, when it was detached by the rubbing of the calf. Another female put on a host on December 1, 1911, dropped fully engorged on December 11.

When development proceeds normally on a host, adult engorgement appears to require from six to 10 days (see Table X). Copulation takes place on the host. The males require a period of three or four days' feeding before mating. The females may be fertilised during any stage of their engorgement after a short feeding period.

TABLE X. *The parasitic period of development of* Dermacentor nigrolineatus.

1912	Infestation No. 1. On bovine.
Sept. 25.	About 500 larvae put on bull.
Oct. 11 (17th day).	1 nymph fully engorged.
,, 14 (20th day).	No ticks found.
,, 19 (25th day).	Another fully engorged nymph found.
,, 21 (27th day).	Nymph last observed has just moulted. Another nymph found.
,, 23 (29th day).	1 female found.
Nov. 1 (38th day).	Female fully engorged. No other ticks found.

1912	Infestation No. 2. On bovine.
Oct. 7, 8.	About 500 larvae put on bull.
,, 15 (8th day).	A larva fully engorged.
,, 19 (12th day).	3 nymphs seen. The largest probably moulted on October 17.
,, 23 (16th day).	Some nymphs fully engorged.
,, 25 (18th day).	The first nymph moulted (♂).
Nov. 1 (25th day).	All nymphs have moulted (several since Oct. 29).
,, 2 (26th day).	First copulation observed. One engorged female dropped off when touched.
,, 4 (28th day).	2 females dropped off.
,, 5 (29th day).	2 engorged females dropped off during examination.
,, 8 (32nd day).	1 female dropped off.
,, 9 (33rd day).	2 females dropped off.

After emerging from the nymphal skin the adult attaches itself near the cast skin which remains attached to the skin of the host. Often the ticks become detached several different times and crawl about for some distance before they begin to show perceptible engorgement. On one occasion nearly all the adults, which had begun to engorge, were observed to migrate from the shoulders and sides of a bovine to the top of the neck where the hair was longer. This may have been caused by a rather sudden drop in the temperature or by a tendency of the adults to seek the protection of longer hair before engorging. The females when well engorged often easily become detached if touched.

Summary of non-parasitic period: The preoviposition period ranges from 122 to 161 days, the oviposition period from 20 to 36 days; the incubation period from 37 to 55 days; the larval longevity from 72 to at least 166 days; and the total non-parasitic period—from the dropping of the engorged females to the death of the last larva—from 243 to at least 360 days. Some of these data are given in more detail in Table VIII.

Economic Importance.

D. nigrolineatus appears to be of little general economic importance although locally it sometimes infests cattle sufficiently to greatly reduce their flesh and vitality. The only locality in which we know of its occurrence as a pest is near Lake, Fentress County, Tennessee. In this district, which is hilly and timbered, the ticks are often found in great numbers on the cattle when they are brought in from the range in the autumn. The backs and hindquarters of the animals are usually the most heavily infested, and certain animals bear far greater numbers of ticks than others in the same herd.

Although this tick is sometimes found in numbers on deer, it is not known to become numerous enough to cause any particular injury to them.

DESCRIPTION OF PLATES X TO XII.

PLATE X.

Figs. 1–4. *Dermacentor hunteri.* (Photographs by G. N. Wolcott.)

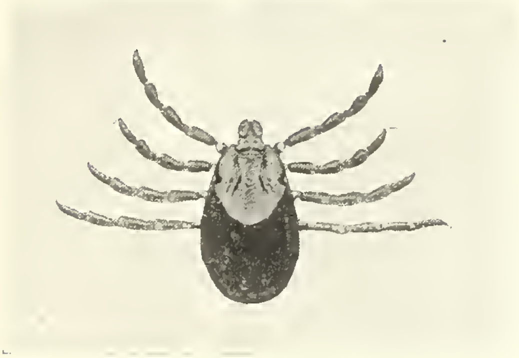
Fig. 1. Unengorged female, dorsal view.
Fig. 2. Unengorged female, ventral view.
Fig. 3. Male, dorsal view.
Fig. 4. Male, ventral view.

Figs. 5–7. *Dermacentor albipictus.* (Photographs by H. P. Wood.)

Fig. 5. Male stigmal plate (right).
Fig. 6. Female stigmal plate (left).
Fig. 7. Spermatophore as left by male after spermatozoa had been pressed out.

Figs. 8–11. *Dermacentor nigrolineatus.* (Photographs by H. P. Wood.)

Fig. 8. Female stigmal plate (right).
Fig. 9. Male stigmal plate (left).
Fig. 10. Engorged nymph, dorsal view.
Fig. 11. Engorged nymph, ventral view.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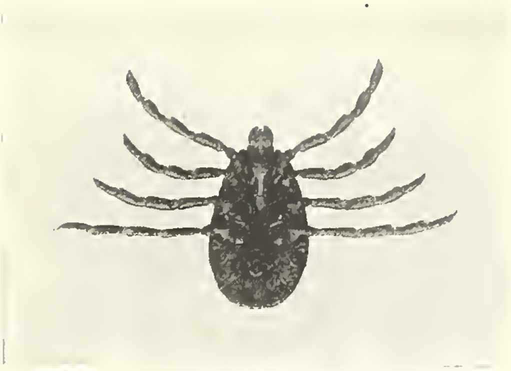
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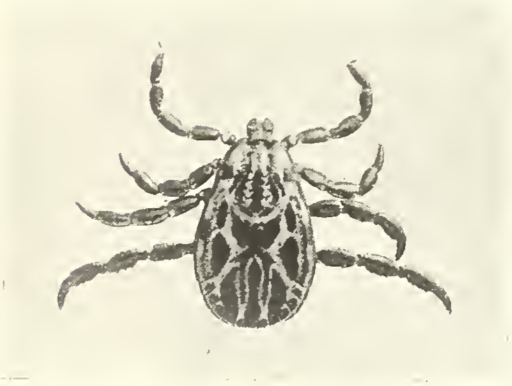
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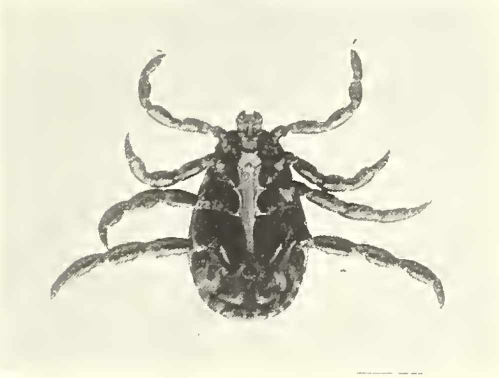
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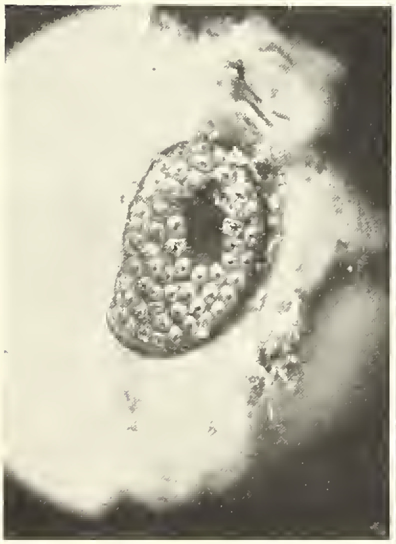
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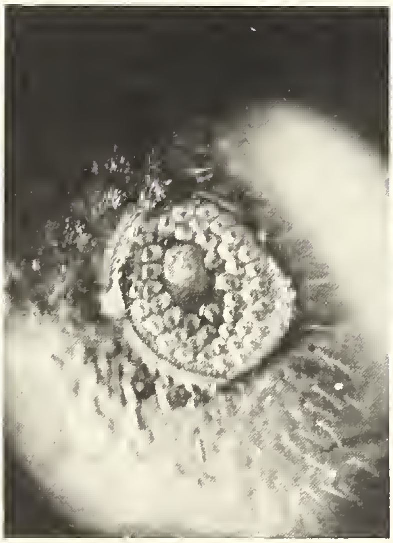
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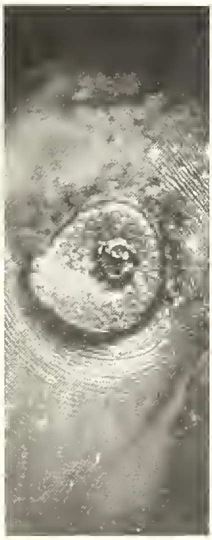
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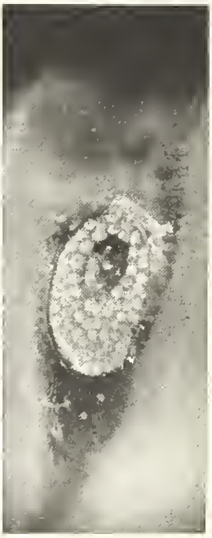
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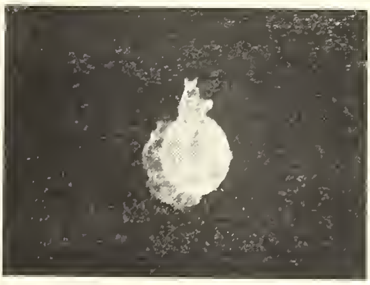
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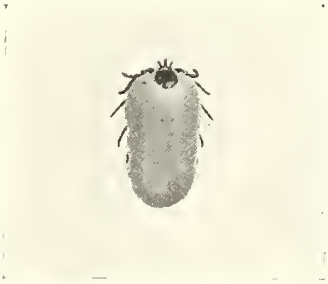
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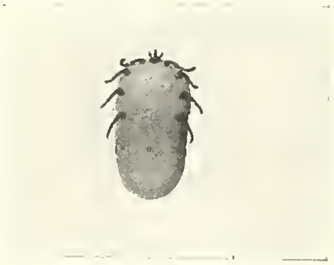
Fig. 11.

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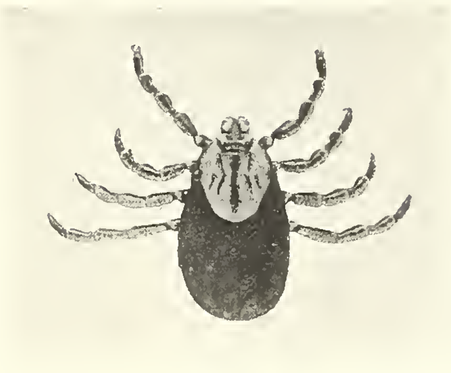

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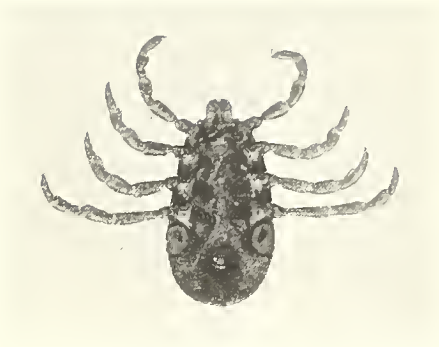

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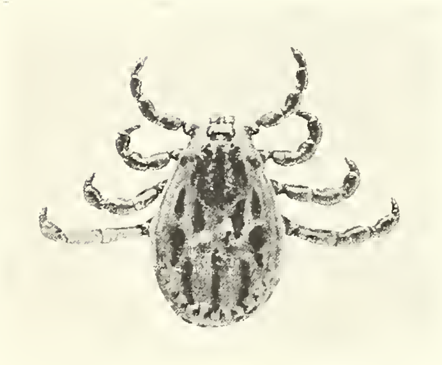

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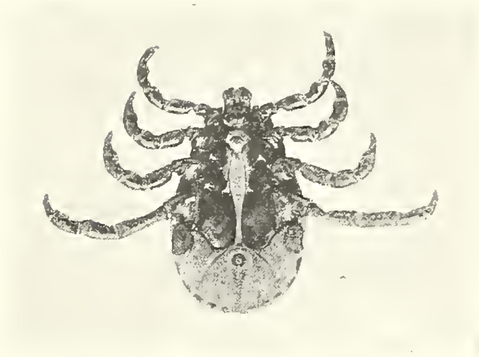

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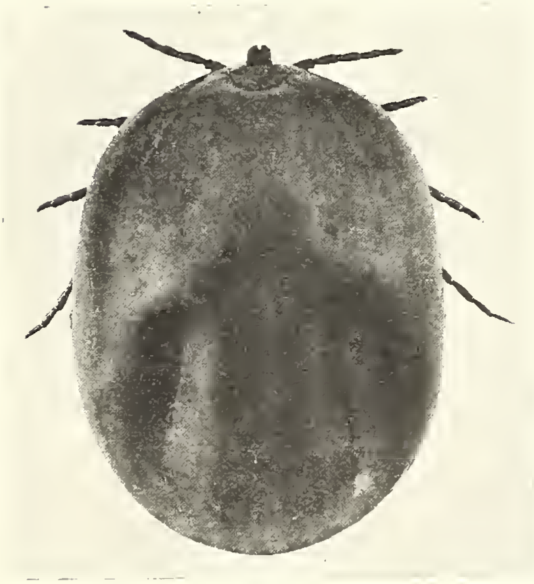

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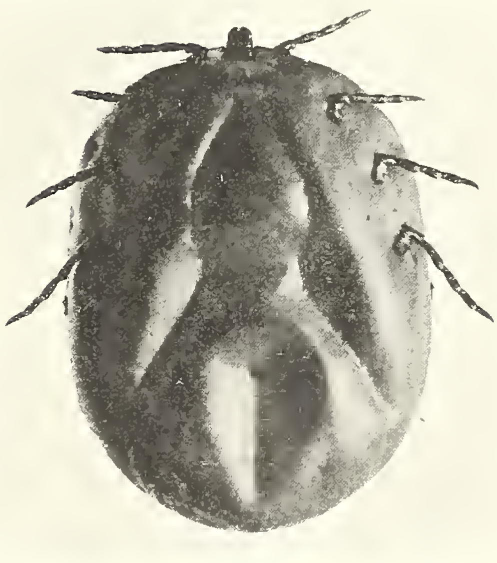

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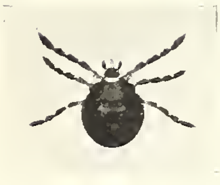

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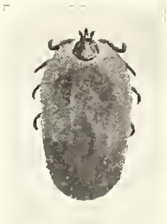

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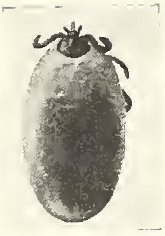

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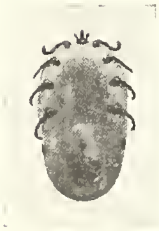

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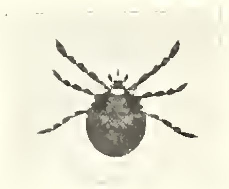

Fig. 11.

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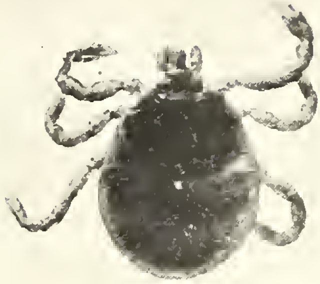

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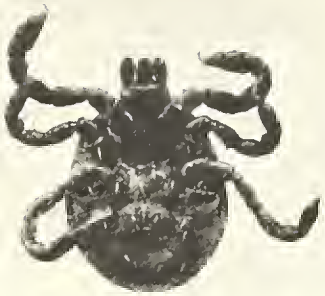

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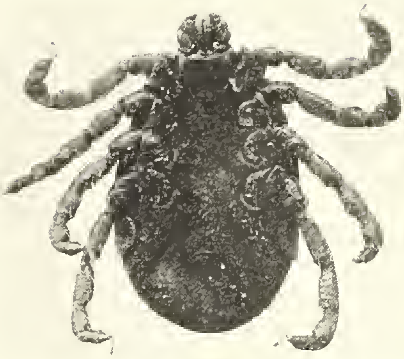

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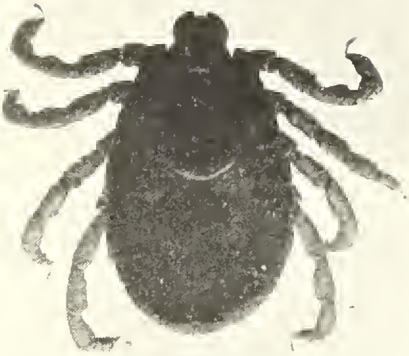

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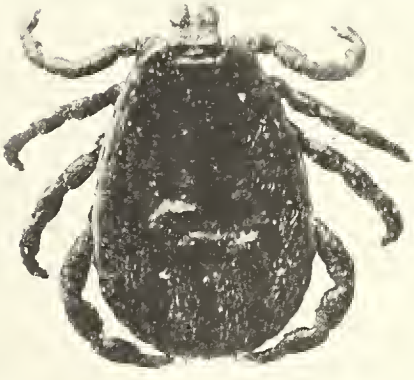

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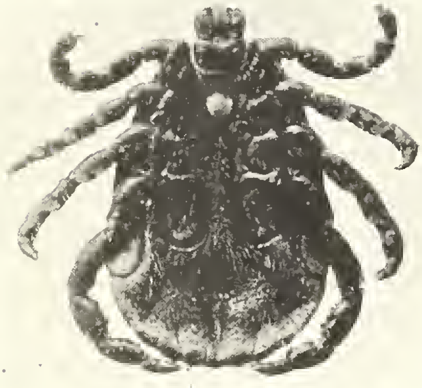

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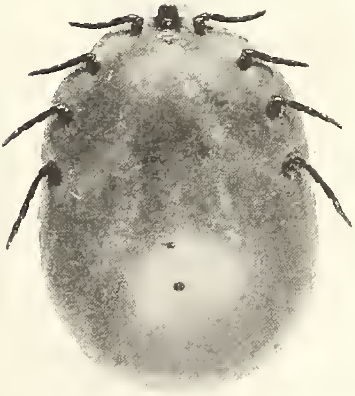

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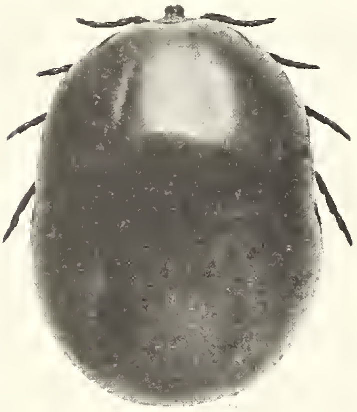

Fig. 8.

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PLATE XI.

Figs. 1–11. *Dermacentor albipictus.* (Photographs Figs. 1–6 by G. N. Wolcott, Figs. 7–11 by H. P. Wood.)

Fig. 1. Unengorged female, dorsal view.
Fig. 2. Unengorged female, ventral view.
Fig. 3. Male, dorsal view.
Fig. 4. Male, ventral view.
Fig. 5. Engorged female, dorsal view.
Fig. 6. Engorged female, ventral view.
Fig. 7. Unengorged larva, dorsal view.
Fig. 8. Engorged nymph, dorsal view.
Fig. 9. Engorged larva, dorsal view.
Fig. 10. Engorged nymph, ventral view.
Fig. 11. Unengorged larva, ventral view.

PLATE XII.

Figs. 1–8. *Dermacentor nigrolineatus.* (Photographs by H. P. Wood.)

Fig. 1. Unengorged larva, dorsal view.
Fig. 2. Unengorged larva, ventral view.
Fig. 3. Unengorged female, ventral view.
Fig. 4. Unengorged female, dorsal view.
Fig. 5. Male, dorsal view.
Fig. 6. Male, ventral view.
Fig. 7. Engorged female (small individual), ventral view.
Fig. 8. Engorged female (small individual), dorsal view.

TREMATODE PARASITES FROM FOOD-FISHES OF THE NORTH SEA.

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Australian Institute of Tropical Medicine,
Townsville, Queensland.

(With Plate XIII.)

The following observations were made in September, 1908, during a short residence at Aberdeen where, through the kindness of Prof. J. Arthur Thomson, I was able to deal with a considerable number of fishes in the very limited time at my disposal[1]. The investigation was intended as a continuation of that already carried out at St Andrews, the object being to examine a number of fishes which could not readily be obtained at the latter place. There the fishes dealt with were mostly littoral forms, but at Aberdeen attention was mainly paid to the larger deep-water fish; of these a plentiful supply could be easily obtained. A few species were re-examined here.

In the course of ten days 79 fish belonging to 23 species were examined and of these 71, *i.e.* 90 % were infected with parasitic worms which were distributed amongst the various classes as follows:

Trematodes in 40 cases (51 %), Cestodes 45 cases (57 %), Nematodes 46 cases (58 %) and Acanthocephala three cases (4 %). As is usually the case in marine Teleostean fishes, the great majority of Cestode and Nematode parasites were larval or immature forms. Only in a single case (*Merluccius merluccius*) was an adult tape-worm found.

In these fishes the frequency of infection was somewhat greater than I had previously had experience of, but the intensity of infection, measured in terms of the variety of parasites in each host, was considerably less. Every species of fish except *Zeugopterus punctatus* (a single specimen) yielded one or more species of parasite. The most varied fauna was found in the witch, *Pleuronectes cynoglossus* (nine species), the horse-mackerel, *Trachurus trachurus* (eight), the halibut, *Hippoglossus vulgaris* (eight), and the long rough dab, *Drepanopsetta platessoides* (seven).

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[1] The expenses of this investigation were defrayed by the Government Grant Committee of the Royal Society.

In addition to the fish dealt with while in Aberdeen, I have since had the opportunity of examining 28 specimens of *Trachurus trachurus* which were kindly sent to me by Dr H. Chas. Williamson, who also sent me specimens of parasites from *Anarrhichas latifrons*, *Raja macrorhyncha* and *Laemargus microcephalus*. The horse-mackerel were examined chiefly for the purpose of obtaining further specimens of *Ancylocoelium typicum* but without success.

The following is a list of the fish examined and the parasites obtained from each. The figures in brackets refer to the number of specimens of each species of fish and the number of times each particular parasite occurred:

1. *Sparus centrodontus*. Sea-bream (11)	
Zoonogenus vividus Nicoll	Rectum (2)
Hemiurus communis Odhn.	Stomach (3)
2. *Trachurus trachurus*. Horse-mackerel (2)	
Ancylocoelium typicum Nicoll	Intestine (1)
Tergestia laticollis (Rud.)	,, (1)
Lecithaster gibbosus (Rud.)	Stomach (2)
Ectenurus lepidus Looss	,, (2)
3. *Scomber scombrus*. Mackerel (6)	
Pharyngora bacillaris (Molin)	Intestine (2)
Lecithocladium excisum (Rud.)	Stomach (1)
4. *Zeus faber*. John Dory (1)	
Lecithaster gibbosus (Rud.)	Intestine (1)
5. *Trachinus draco*. Greater Weever (1)	
Hemiurus communis Odhn.	Stomach (1)
6. *Lophius piscatorius*. Angler (2)	
Derogenes varicus (Müll.)	,, (1)
Hemiurus communis Odhn.	,, (1)
Bucephalus gracilescens (Rud.)	Intestine (1)
7. *Gadus pollachius*. Pollack (1)	
Hemiurus communis Odhn.	Stomach (1)
Bucephalus gracilescens (Rud.) immature	Stomach (1)
8. *Merluccius merluccius*. Hake (3)	
Derogenes varicus (Müll.)	,, (2)
Hemiurus ocreatus (Rud.)	,, (2)

9. *Brosmius brosme.* Tusk (4)	
Derogenes varicus (Müll.)	Stomach (2)
Hemiurus communis Odhn.	,, (1)
10. *Pleuronectes cynoglossus.* Witch (7)	
Steringophorus furciger Olss.	Intestine (2)
Zoogonoides viviparus (Olss.)	Rectum (2)
Cercaria cestoides nov.	Stomach wall in cyst (1)
11. *Pleuronectes limanda.* Common Dab (5)	
Hemiurus communis Odhn.	Stomach (1)
12. *Pleuronectes microcephalus.* Lemon Dab (1)	
Derogenes varicus (Müll.)	Stomach (1)
13. *Drepanopsetta platessoides.* Long rough Dab (7)	
Steringophorus furciger (Olss.)	Intestine (1)
Rhodotrema ovacutum (Lebour)	,, (3)
Zoogonoides viviparus (Olss.)	Rectum (3)
14. *Conger conger.* Conger eel (1)	
Lecithochirium rufoviride (Rud.)	Stomach (1)
15. *Anarrhichas latifrons.* Spotted Cat Fish (1)	
Lebouria idonea Nicoll	Intestine (1)
16. *Raja macrorhyncha* (1)	
Otodistomum cestoides (van Ben.)	Stomach (1)

Most of the parasites collected are common and well-known forms and only in a few cases are brief notes necessary.

Stephanochasmus baccatus Nicoll.

(Pl. XIII, fig. 1.)

Five specimens of this species were obtained from the rectum of a halibut (*Hippoglossus vulgaris*). They were somewhat smaller than the specimen from which the original description (Nicoll, 1907, p. 80, Pl. 11) was made. The smallest individual measures 2 mm. in length and contained only one ovum, so that it may be assumed that the species does not begin to produce ova till it reaches this size. The length of the mature specimens is 2-3·3 mm. and the average 2·6 mm. In a specimen of this length the maximum breadth is ·56 mm. and is usually to be found in the testicular region, although sometimes it is across the ventral sucker. As a rule the neck is somewhat more slender than is shown in the original figure. It widens gradually till the ventral sucker is reached, beyond which the body becomes narrow but broadens out again towards the posterior end. The latter is rounded but

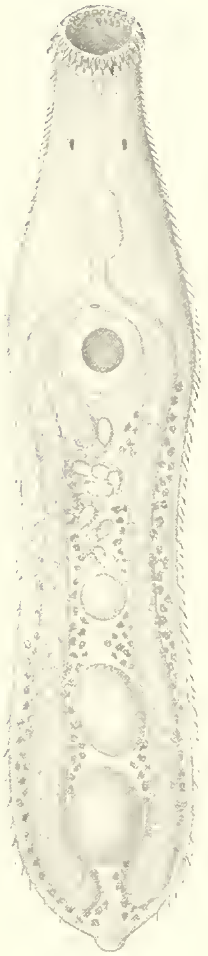

Fig. 1.

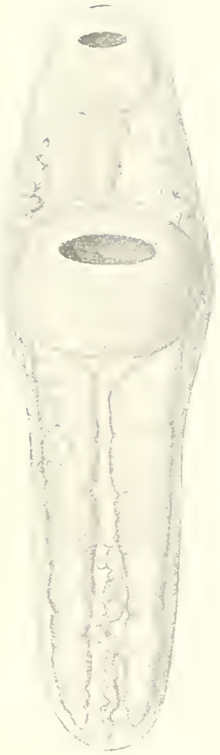

Fig. 2.

M. Rhodes, del.

Fig. 1. *Stephanochasmus baccatus* Nicoll. ×40.
Fig. 2. *Otodistomum cestoides* (van Ben.). Cercaria. ×40.

usually presents a distinct terminal protuberance and this marks the aperture of the excretory vesicle.

The cuticular spines are more extensive than was originally supposed and in some specimens they can be traced almost to the posterior end of the body. The cephalic spines could be counted in only two specimens, in one of which they numbered 30, in the other 29, in each row. In addition, occasionally, intercalary spines were observed much smaller than the normal spines and having apparently no definite arrangement. The spines of the anterior row measure 0·033 mm., and those in the posterior row 0·039 mm., in length.

A feature which passed unnoticed in the original specimen was the presence of two crescentic eye-spots situated midway between the oral sucker and the pharynx. They are probably persistent in all species of the genus. Owing to the fact that the original specimen was somewhat contracted the neck appeared somewhat shorter than is normally the case. On an average it is about one-third of the body length (0·88 mm.).

The oral sucker is of very variable size and shape. Sometimes it appears as a shallow cup with a wide mouth, at other times as a deeper structure with a comparatively narrow aperture. Its average diameter is 0·21 mm., but it varies from 0·15 mm. to 0·27 mm. The ventral sucker, which is approximately globular, is of much more constant size, its average diameter being 0·27 mm. The sucker ratio is therefore about 7 : 9.

The pre-pharynx varies in length, with the state of extension, from 0 07 mm. to 0·3 mm., the average being 0·25 mm. Similarly the oesophagus varies from 0·03 mm. to 0·17 mm., with an average of 0·08 mm. The pharynx measures 0·2 × 0·13 mm.

The testes are usually contiguous or separated by a very small space. They measure 0·29 × 0·26 mm. and the post-testicular space is usually equal to the long diameter of the testes. As a rule the axis of the testes is slightly oblique, the anterior end being displaced a little to the right side. This is more marked in the case of the anterior testis.

The ovary lies a little in front of the anterior testis from which it is usually separated by a number of yolk follicles. It is displaced somewhat to the right side and is nearly globular with a diameter of 0·16 mm. The yolk glands are uninterrupted and extend from the posterior border of the ventral sucker to the end of the body but they do not fuse in the post-testicular space. The follicles surround the intestinal diverticula except on the inner side. There is a small yolk reservoir on the left of the ovary. A long Laurer's canal is present, but no receptaculum seminis.

The genital aperture is situated in the middle line immediately in front of the ventral sucker. The cirrus-pouch is small and slender. As a rule it extends about 0·14 mm. behind the ventral sucker. It contains a small, simple vesicula seminalis, a short pars prostatica and a long ductus ejaculatorius. No spines could be detected either in the cirrus or in the vagina. The latter is about the same length as the cirrus-pouch and lies to its left side. The uterus is confined to the median field and is of short extent. Its initial part is filled with spermatozoa and the ova are usually few in number. They measure 0·094 × 0·047 mm., and have the characteristic shape indicated in the previous description.

Family **FELLODISTOMIDAE** n. nom.

Steringophoridae Odhner, 1911.

Odhner's proposal (1911, p. 98) to change the name *Fellodistominae* to *Steringophorinae* has little to justify it. The former name was perhaps not the most happy choice and it may readily be admitted that as a matter of taste the latter is more appropriate. It is surprising, however, to find an experienced systematist such as Odhner allowing himself to be swayed by such a consideration. It is obvious that the name *Steringophorinae* cannot stand but must give place to the earlier *Fellodistominae.* The name of the family should consequently be changed to *Fellodistomidae.*

Tergestia laticollis (Rud.).

Only a single specimen of this parasite was obtained from the intestine of the horse-mackerel (*Trachurus trachurus*). It is apparently not a common parasite in the North Sea, but it is comparatively frequent on the south coast.

An amended description of the species has recently been published by Odhner (1911, p. 111) but the dimensions which he gives for the various structures are somewhat misleading. They can only apply to specimens of an average size, which, although not stated by Odhner, is probably about 2·5 mm.

In my collection of specimens from the south coast I have found the average length to be 2·65 mm. of which the neck comprises exactly one-third. The maximum breadth across the ventral sucker is about one-sixth of the body length. The oral sucker has a transverse diameter of 0·19 mm. but it is almost invariably elongated, and especially in extended specimens. The long diameter is about 0·23 mm. The ventral sucker is almost globular and was never found so markedly oval as Odhner represents it. Its dimensions are 0·28 × 0·29 mm. The ratio of the transverse diameter is therefore approximately 2 : 3 and the diameter of the ventral sucker is about one-ninth of the body length.

The pharynx measures 0·25 × 0·10 mm. The intestinal bifurcation is not quite so far back as Odhner represents it, but usually occurs about the posterior border of the ventral sucker. In other respects my specimens agree with Odhner's description, though it is worthy of note that the position of the lateral cuticular folds is not constant in relation to the pharynx. In the state of extension the pharynx is drawn forwards, the space between the folds is increased and three or even four may come to be situated behind the pharynx.

The specimen from Aberdeen exceeded the limit assigned by Odhner for the maximum size of the species, as it measured 4·6 mm. in length. The sucker ratio is the same but the suckers are relatively smaller, the ventral being only one-thirteenth of the body length. The yolk glands again extend only half-way between the ovary and the ventral sucker. The oesophagus is not straight but is twisted into the form of an **S** and is much dilated.

Lecithochirium rufoviride (Rud.).

In the stomach of *Conger conger*, amongst a large number of specimens of *Lecithochirium rufoviride*, two specimens were conspicuous by their creamy-white colour, in striking contrast to the blood-red hue of the others. It seemed almost certain that they must belong to a distinct species, but on close examination no features of difference could be detected and the specimens must therefore be regarded as albino individuals of *L. rufoviride*. They were rather large specimens, the body in one measuring 6·4 mm. and the appendix 1·6 mm. The oral sucker had a diameter of 0·7 mm. and the ventral 0·82 mm. In the other specimen the body measured 7·3 mm. in length.

Otodistomum cestoides (van Ben.).

This large parasite from the oesophagus of the rays has been recorded on two occasions from British waters, first by Miss Lebour (1908 p. 39) from *Raja radiata* and later (as *Distomum veliporum*) by T. Scott (1909 p. 77) *from Raja batis*. I have here to record its occurrence in *Raja macrorhyncha*, from which it was collected by Dr H. C. Williamson.

In regard to the life history of this species it is probable that the cercaria discovered by Scott, encysted in the stomach wall of the witch, *Pleuronectes cynoglossus*[1], represents the larva of *O. cestoides*. In the same fish I have found encysted in the wall of the stomach a cercaria, which from its large size and general structure cannot be referred to any other species. It occurred as a large orange-yellow globular cyst 1·95 mm. in diameter, firmly attached to the outer wall of the stomach by a short pedicle. The wall of the cyst consisted of a thick tough outer coat within which was a large amount of viscous yellow material. The cercaria measured 2·4 mm. in length, with a maximum breadth across the ventral sucker of 0·66 mm. Both suckers were transversely elongated, the oral measuring 0·29 × 0·35 mm. and the ventral 0·43 × 0·59 mm. The latter was situated at a distance of 0·96 mm. from the anterior end. The pharynx was small and situated close to the oral sucker. There was a very short oesophagus and wide diverticula extending in a slightly sinuous manner to the posterior end of the body. The excretory vesicle was Y-shaped and consisted of a median stem extending a quarter of the length of the body, and two lateral branches reaching forward as far as the pharynx. No other organs were visible.

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[1] In Scott's paper this species is inadvertently named *P. microcephalus*.

RHIPICEPHALUS APPENDICULATUS: VARIATION IN SIZE AND STRUCTURE DUE TO NUTRITION.

By GEORGE H. F. NUTTALL, F.R.S.

(*From the Quick Laboratory, University of Cambridge.*)

(With 4 Text-figures.)

In the course of our studies on species of *Rhipicephalus*, we have noted the great variability in size and structure observable in the genus. This variability has been a cause of much confusion in classification, as noted by Warburton (*Parasitology*, 1912, v. 1). It soon occurred to me, in seeking for an explanation of this variability, that it might well be due to nutrition, it being probable that, under natural conditions, a certain number of ticks are removed from the host before they have fed to repletion. When a host is infested with ticks it will brush or rub off a certain number prematurely and the ticks which are imperfectly fed would, doubtless, give rise to adults of small size. As stated, the great variability observed in *Rhipicephalus* is very striking. In the genus *Ixodes*, on the other hand, the size of the adults is fairly constant. In the latter case, we have, as a rule, to deal with small ticks provided in the immature stages with long hypostomes, both the small size and hypostomal structure rendering it most difficult for the tick to be removed prematurely from the host. It is difficult to remove *Ixodes* from the host without breaking the hypostome and using considerable force. In *Haemaphysalis*, as in *Rhipicephalus*, the immature stages are provided with short hypostomes and the ticks are more readily removed. The variation in size noted in adult *Haemaphysalis*, whilst considerable, is not as great as in *Rhipicephalus*, which would appear to be attributable to the smaller size of the tick, being in a measure a protection against its being prematurely removed from the host.

My assumption that small forms arise through malnutrition owing to premature removal of the immature stages from the host has been confirmed by Aragão (1911–1912)[1], who has disposed of Neumann's *Amblyomma cajennense* var. *parviscutatum* by picking off nearly replete nymphs of *A. cajennense* from the host. From the imperfectly fed nymphs there emerged adults of small size. He thus obtained *A. cajennense* females ranging from 5·3 mm. in length (normal) down to 3·7 mm., *i.e.* a proportion of 100 : 70. He has obtained similar results with *A. agamum.*

The variation in size observed by Aragão for *Amblyomma* does not nearly approach what I have obtained experimentally with *Rhipicephalus appendiculatus* for, in one series of observations, we removed from the host partially fed larvae as well as nymphs and consequently obtained small nymphs and small adults.

A lot of hungry larvae (Fig. 1), the progeny of a single female, were placed upon a calf on 28. XI. 1912. Their subsequent history was as follows[2]:

A	B
150 larvae, partly gorged, were picked off the calf on 2, 3 and 4. XII. 1912, *i.e.* on the 5–7th day.	733 larvae, fully gorged, dropped off the calf on 2–7. XII. 1912, *i.e.* on 5–10th day.
50 nymphs emerged on 14–18. XII. 1912: metamorphosis lasted 12 days. All of these nymphs were placed on a calf on 2. I. 1913.	Nymphs emerged on 12–17. XII. 1912: metamorphosis lasted 10 days. All of these nymphs were placed on a calf on 15. I. 1913.

C	D	E	F
20 nymphs, partly gorged, were picked off calf on 6 and 7. I. 1913, *i.e.* on the 5–6th day.	12 nymphs, fully gorged, dropped off calf on 7–14. I. 1913, *i.e.* on the 6–13th day.	355 nymphs, partly gorged, were picked off calf on 17–24. I. 1913, *i.e.* on 3–10th day.	148 nymphs, fully gorged, dropped off calf on 18–29. I. 1913, *i.e.* on 4–15th day.
Adults emerged on 21–28. I. 1913: metamorphosis lasted 15 days.	Adults emerged on 23–30. I. 1913: metamorphosis lasted 16 days.	Adults began to emerge on 4. II. 1913: metamorphosis lasted 17 days.	Adults emerged on 5-16. II. 1913; metamorphosis lasted 17 days.
Adults: Set I.	Set II.	Set III.	Set IV.

It will be seen from the foregoing record that the larvae were allowed to feed either (A) partially, or (B) to repletion upon the host; that the nymphs which developed from partially fed larvae (A) were in turn allowed to feed (C) partially, or (D) to repletion; and that the nymphs which developed from fully fed larvae (B) were similarly allowed to feed either (E) partially, or (F) completely. The adults of Set I had, therefore, developed from larvae and nymphs which had not been allowed to feed to repletion; the adults of Set II had developed from incompletely fed larvae which, as nymphs, were fed to repletion; the adults of Set III had developed from larvae fed to repletion which, as nymphs, were incompletely fed; whereas the adults of Set IV (controls) developed from larvae and nymphs which had both been fed to repletion.

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[1] Aragão, H. de B. (1912), "Beiträge zur Systematik und Biologie der Ixodidae." *Mem. do Inst. Oswaldo Cruz*, IV. 96–119, 2 pls., 6 text-figs.

[2] The ticks were all maintained at the same temperature (64–70° F.) during metamorphosis and raised, enclosed in bags, upon the ears of calves housed in a warmed stall (56–60° F.). Only the minimum periods of time required for metamorphosis are stated.

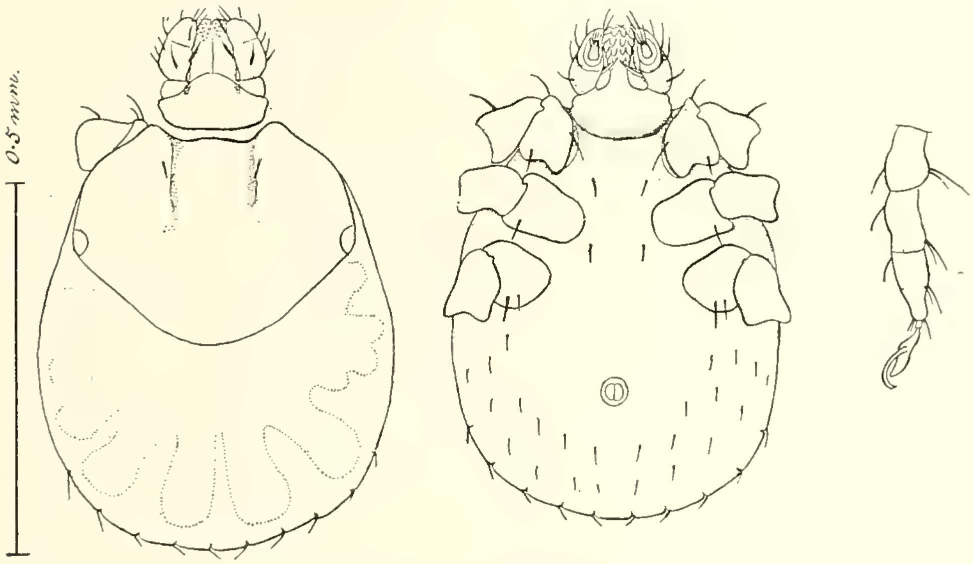

Fig. 1. *Rhipicephalus appendiculatus*, unfed larva: dorsal and ventral aspects, tarsus 4. Lot 2149. G.H.F.N. del.

Variation in Nymphs (*R. appendiculatus*). Fig. 2.

Of the partially fed larvae in Lot A a certain number died owing to the mechanical injury they had sustained in being forcibly removed from the host. Those that survived and underwent metamorphosis varied considerably in size as will be seen by reference to the following table in which measurements of the nymphs which emerged in Lot A and Lot B are given.

The following measurements are in mm., the length and breadth of the body being given exclusive of the capitulum. The unfed nymphs, which were all measured whilst alive, are arranged in order of size:

Measurement of Nymphs which emerged:

A. From partially gorged larvae.

No.	Length	Width
1	0·8	0·52
2	0·84	0·64
3	0·92	0·6
4	1·0	0·68
5	1·0	0·8
6	1·08	0·8
7	1·28	0·92
8	1·28	0·68
9	1·4	1·04
Average	**1·07**	**0·74**

B. From normally gorged larvae.

No.	Length	Width
1	1·28	0·92
2	1·32	0·88
3	1·32	0·88
4	1·32	0·88
5	1·32	0·84
6	1·32	1·0
7	1·36	1·0
8	1·44	0·92
9	1·44	0·92
Average	**1·35**	**0·92**

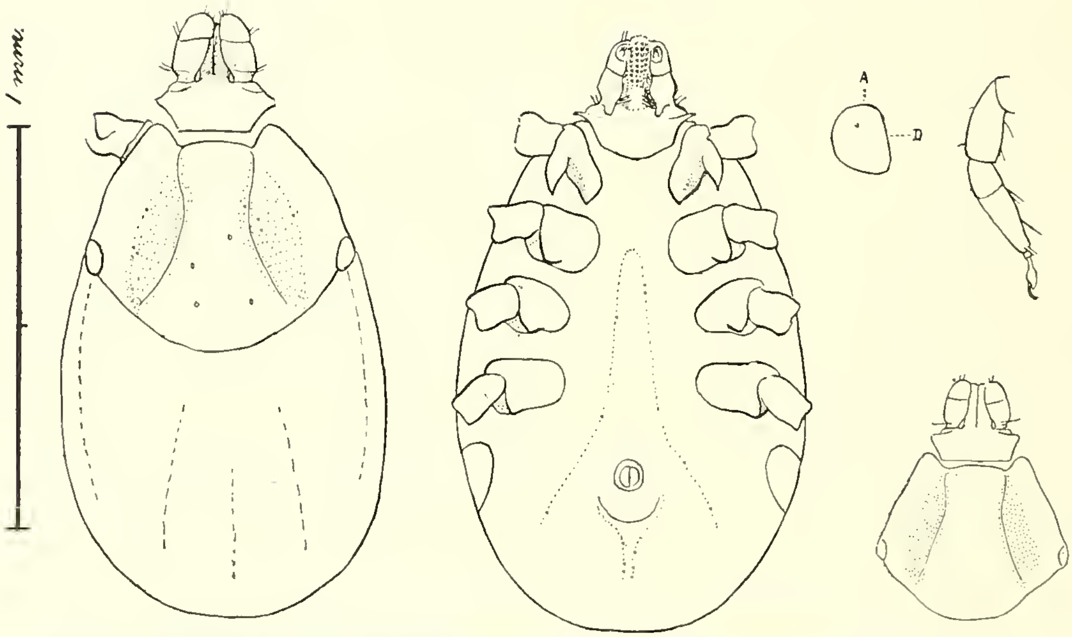

Fig. 2. *Rhipicephalus appendiculatus*, nymphs: (*a*) normally developed unfed specimen, dorsal and ventral aspects, spiracle and tarsus 4; (*b*) capitulum and scutum of nymph which emerged from a larva removed from the host before it had fed to repletion. Lot 2149. G.H.F.N. del.

The smallest of Lot A (No. 1) was only 62 % as long as the smallest of Lot B (No. 1), and the larger specimens of Lot A (Nos. 2–6) only attained 84 % of the length of Lot B (No. 1). Lot A Nos. 7 and 8 were about as large as the smallest of Lot B, and only one of Lot A (No. 9) attained a normal size. The variation in size in Lot A was therefore very considerable, the difference in length between the smallest and largest being as 57 : 100, whereas in Lot B the difference was only as

88 : 100. There being numerous specimens in Lot B, the largest and smallest which could be found were measured; the greater variation observed in Lot A is, therefore, all the more striking, and it is clearly attributable to the larvae having been removed from the host at different stages of engorgement.

Variation in Adults. Figs. 3 and 4.

We now come to the adults which emerged from the nymphs of Lots C, D, E and F respectively. (The signs L and O denote Larvae and Nymphs respectively.)

		measured	The largest
In Lot C, picked as L and O, the smallest	♂	1·8 × 1	1·8 × 1·1
,, ,, ,, ,, ,,	♀	1·8 × 1	2·5 × 1·5
In Lot D, picked as L but fully gorged as O's,	♂	2·8 × 1·9	3·8 × 2·5
do.	♀	2·9 × 1·8	3·8 × 2·3
In Lot E, gorged as L but picked as O's,	♂	2·2 × 1·3	4·3 × 3·8
do.	♀	2·0 × 1·3	3·8 × 2·4
In Lot F, normally fed as L and O's,	♂	3·0 × 2·0	4·4 × 2·8
do.	♀	3·5 × 2·2	4·3 × 2·8

The time occupied in feeding upon the host and in metamorphosis varied in individuals, and did not appear to be influenced by the picking process during the previous stage.

Out of 26 lots of *R. appendiculatus* collected in Africa off hosts, the smallest and largest ♂s were measured. The smallest ♂ measured 1·9 mm. in length, the largest 4·4; a considerable variation is observable in ticks taken from the same host. It is clear, therefore, that we have reproduced, under experimental conditions, *large and small forms of ticks comparable with those observed in nature.* Our smallest male produced experimentally measured 1·8 mm. in length. There, nevertheless, remains a considerable *normal* variation in size which has to be reckoned with; in Lot F the males varied between 3 and 4·4 mm. in length. I may add that the small adults of Lot C, picked as L and O's, were placed upon a host and behaved in a normal manner, the ♀s attaining almost a normal measurement when engorged (10 × 7 mm.) and laying eggs of normal size. The experiments are being continued and will be reported upon in a future paper.

It should be noted that the smallest adults were obtained from individuals picked as larvae and nymphs (Lot C). They varied most in size when picked as nymphs but not as larvae (Lot E), ranging from very small forms to sizes within the normal range. When picked as L

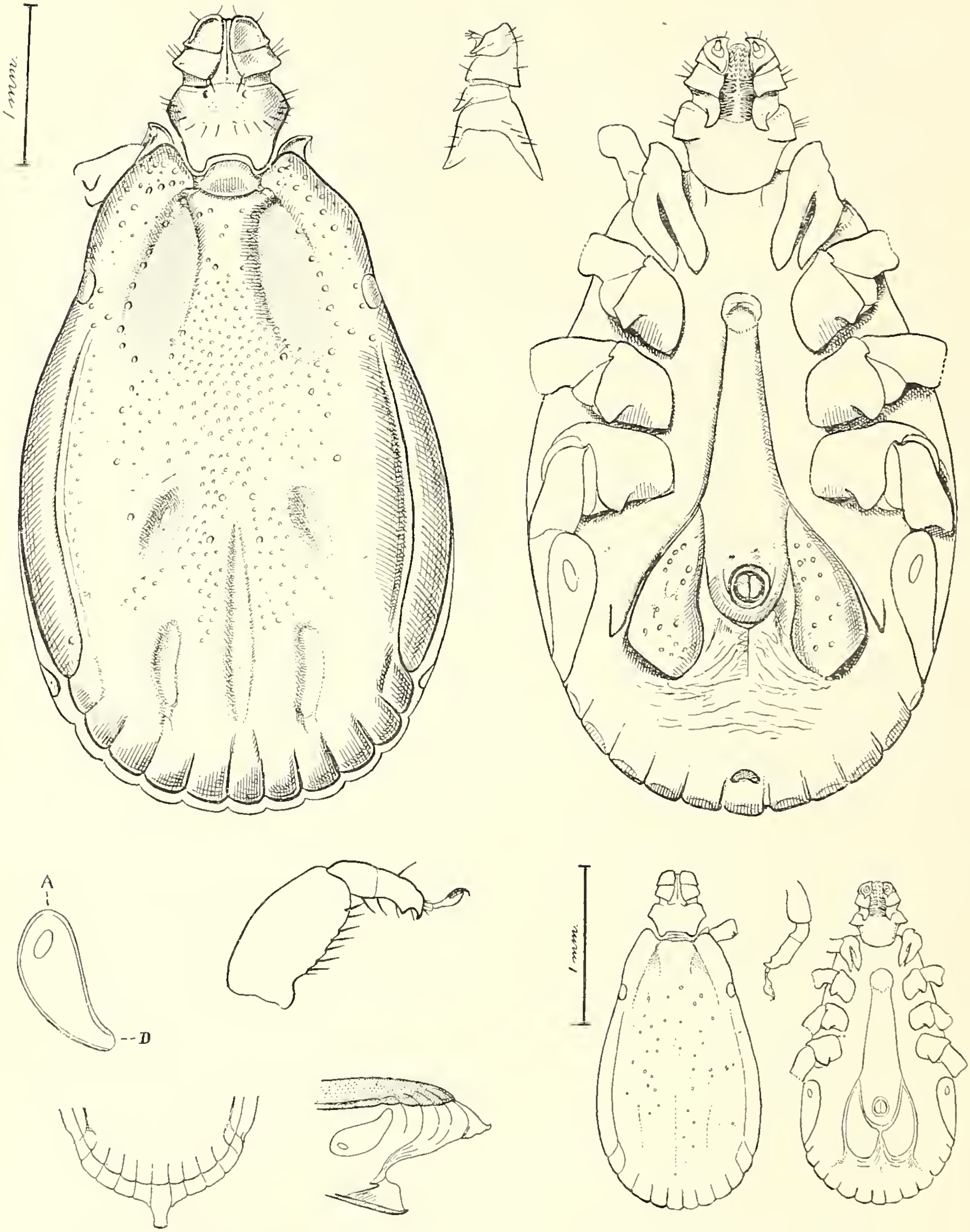

Fig. 3. *Rhipicephalus appendiculatus*, males: (*a*) normally developed unfed specimen in dorsal and ventral aspects, capitulum in profile, spiracle and tarsus 4; (*b*) dorsal and lateral aspects of a fully fed male (less magnified) showing caudal protrusion and the protruding adanal plates with the abdomen distended beyond the contour of the scutum; (*c*) small male which was removed from the host in the larval and nymphal stages before it had fed to repletion. The large and small males (brothers) are drawn to the same scale. Lot 2149. G.H.F.N. del.

and allowed to feed fully as O's (Lot D) they almost attained a normal size. Apart from differences in size, the ticks which had been subjected to the picking process showed differences in structure.

The normal *nymph* (Fig. 2) varies somewhat in structure, as follows: *Scutum*: the depressed areas between the cervical grooves and lateral ridges are at times well marked, sometimes they are not. In the small ill-nourished specimens the scutum is considerably smaller with straighter antero-lateral and sinuous postero-lateral margins; the basis capituli is less protruding laterally, and the protuberance is situate more anteriorly. The other differences between normal and ill-nourished O's are trivial.

There are considerable differences between normal and small ill-nourished *males* (Fig. 3). The latter appear less chitinized and paler; the scutum is much smoother, shows but faint lateral grooves and is much less punctate; the palps do not show a concavity distally upon the dorsal surface, the characteristic transverse row of hairs upon the basis capituli is absent, and the base appears shorter; the anal plates are rounded posteriorly and almost touch behind the anus, they scarcely protrude above the surface of the abdomen and the accessory adanal plates are absent; the legs are markedly different, this being especially evident in pair IV, where the tarsus and protarsus are nearly of equal width instead of the latter being large and swollen.

In ill-nourished *females* (Fig. 4) the porose areas are minute, the scutum appears less punctate, less depressed outside the cervical grooves, which are short; the lateral ridges are absent. The tarsi are unarmed as in the nymph, to which it approximates more closely in general appearance than does the well-developed female.

To summarize: Our experiments show that there is a considerable individual variation in the size of adult *R. appendiculatus* whose development has not been interfered with. The structural variations in such forms are slight. The great variation in size and structure observable in the genus is, however, merely due to the imperfect nutrition of smaller individuals in their immature stages. It is only by determining the range of variability under experimental conditions that the limits of a species in this respect can be determined and the making of bad species prevented.

The variability in size and structure observed in *R. appendiculatus*, raised under experimental conditions, agrees with what we have found in this species of tick collected from different hosts under natural conditions. Arranging the specimens in series from the largest to the smallest, all grades of modification in the various structures between the

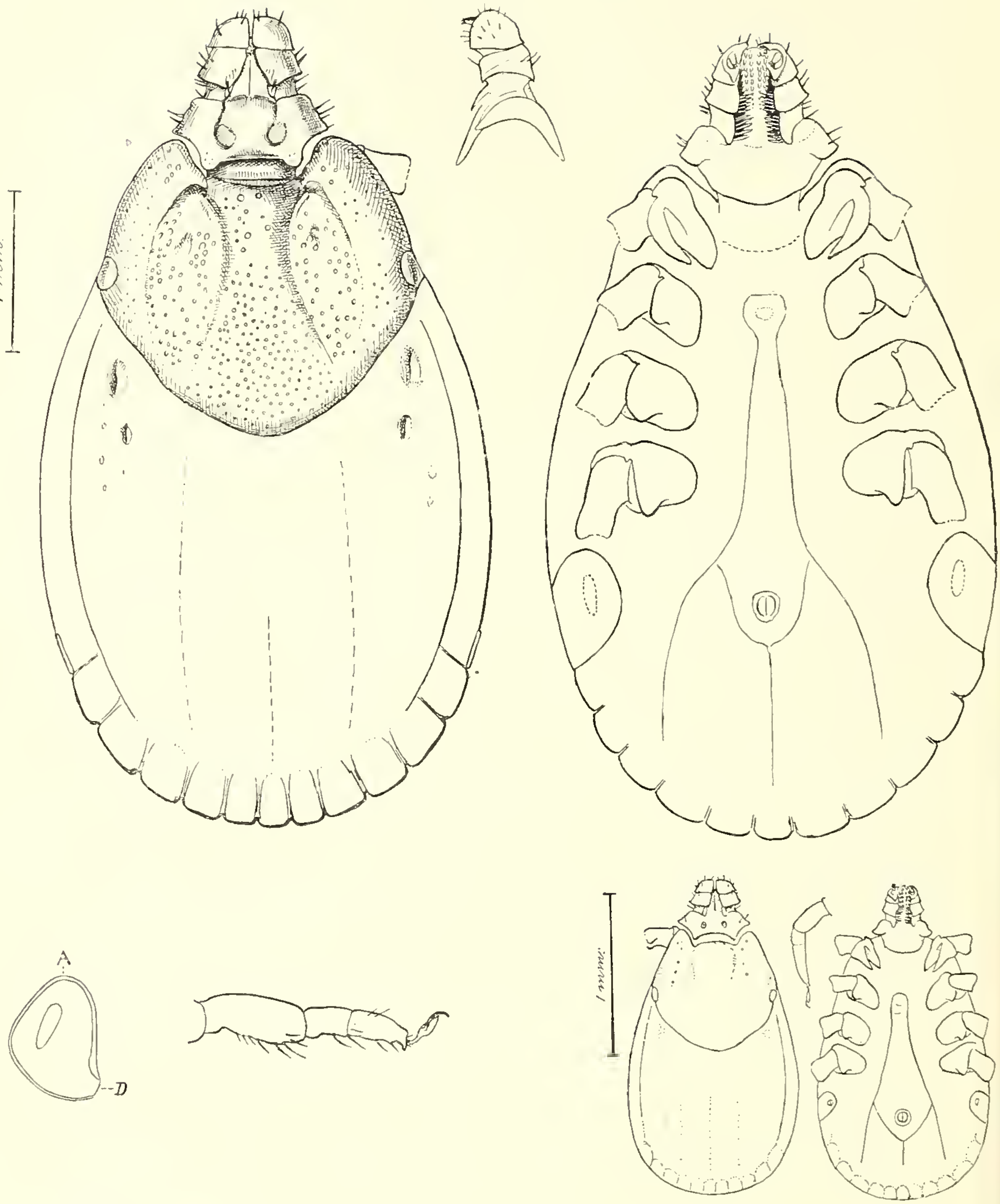

Fig. 4. *Rhipicephalus appendiculatus*, females: (*a*) normally developed unfed specimen in dorsal and ventral aspects, capitulum in profile, spiracle and tarsus 4; (*b*) small female which was removed from the host before it had fed to repletion both as a larva and nymph. The large and small females (sisters) are drawn to the same scale. Lot 2149. G.H.F.N. del.

extremes I have figured can be observed. As we look down the series the scutal punctations grow less marked, the adanal spines gradually dwindle and disappear, the anal plates grow rounded posteriorly and become less and less prominent, the caudal protrusion in replete males dwindles, the protarsus appears less and less swollen, etc., etc. Therefore, the determination of specimens possessing intermediate characters will only be possible when they can be compared to members of an authentic series like the one which we have raised experimentally from a single parent.

In the following paper by Mr Norman Cunliffe the variability of *R. pulchellus* in size, structure and ornamentation forms the subject of a careful study which I requested him to undertake upon this well defined species. Mr Cunliffe's results confirm mine in all essential particulars.

THE VARIABILITY OF *RHIPICEPHALUS PULCHELLUS* (GERSTÄCKER, 1873),

TOGETHER WITH ITS GEOGRAPHICAL DISTRIBUTION.

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(With 6 Text-figures.)

It has been pointed out by Warburton (1912) that the degree of variation within the species of the genus *Rhipicephalus* is very considerable, and in view of this fact it is important to investigate the range of a species and the value of the differential structural characters upon which species are based. The great majority of the *Rhipicephali* are inornate and this, in conjunction with the general lack of distinguishing structural features and the wide variation found within the species, renders determinations difficult. As *Rhipicephalus pulchellus*, however, possesses a characteristic and well-marked ornamentation, which is subject to but slight variation, any specimen, at least in the case of the males, may be determined without difficulty.

Hence this species is invaluable for such an inquiry, and as a casual observation of a number of specimens obtained from one host showed a great range in size, Prof. Nuttall suggested that I should examine critically a number of individuals collected under natural conditions. The material available for observation in Cambridge has been collected in Africa during a period of nine years. Of each consignment received, it has been customary to return a number of specimens after determination and to retain the largest and smallest individuals. Thus it is probable that the naturally-occurring extremes have now been received. The retention of the extremes applies more particularly to the males, in which the variation in size of the scutum is more noticeable than in the females. This artificial selection and the limitation of the number of individuals (the species having a restricted distribution and being somewhat rare) have rendered the results of the investigation less instructive than they would otherwise have been.

We are only concerned with the variability of those structural characters which are usually employed in determining a species of this genus. It should be pointed out that there is a regular gradation of all the characters, described and figured for the largest and smallest specimens respectively (the characters of any individual being correlated with its size) unless the contrary is stated.

Size of Scutum.

The variation in the size of the scutum is the most striking feature. The measurements were made by means of verniers on a moveable-stage microscope, the ocular of which contained a pointer, a method which has been found very useful by Prof. Nuttall. A series of ticks, suitably orientated on a ridge of plasticine fixed to a glass slide, could be moved rapidly in the desired direction and measurements accurate to 0·1 mm. were easily obtainable. The limits of the ornamentation, which in both male and female practically covers the scutum, were used in place of the limits of the scutum itself, because in the majority of cases the exact margin of the scutum is vague. In the male the length was considered to be from the anterior emargination to the posterior border, the breadth across the posterior third, the scutum being broadest at that position; in the female, the length was measured as in the case of the male and the breadth immediately posterior to the eyes.

The results of the measurements of the scuta of 75 males and 53 females are given in the form of correlation diagrams (Figs. 1 and 5). The male scutum increases more rapidly in width than in length, giving a large specimen a somewhat truncated appearance, which contrasts with the oval form of a dwarf. A glance at the correlation diagram (Fig. 1) for the male individuals shows that the correlation between length and breadth, as would be expected, is very close, the correlation coefficient being as high as 0·93. It indicates the division, which is more clearly expressed in the frequency curve, of the individuals into two groups, and also enables the dimensions of the average sized scutum to be determined easily. For the male scutum, the extreme and average measurements are as follows:

	Length in mm.	Breadth in mm.
Largest specimen	4·4	3·4
Smallest specimen	2·4	1·6
Average specimen	3·2	2·3

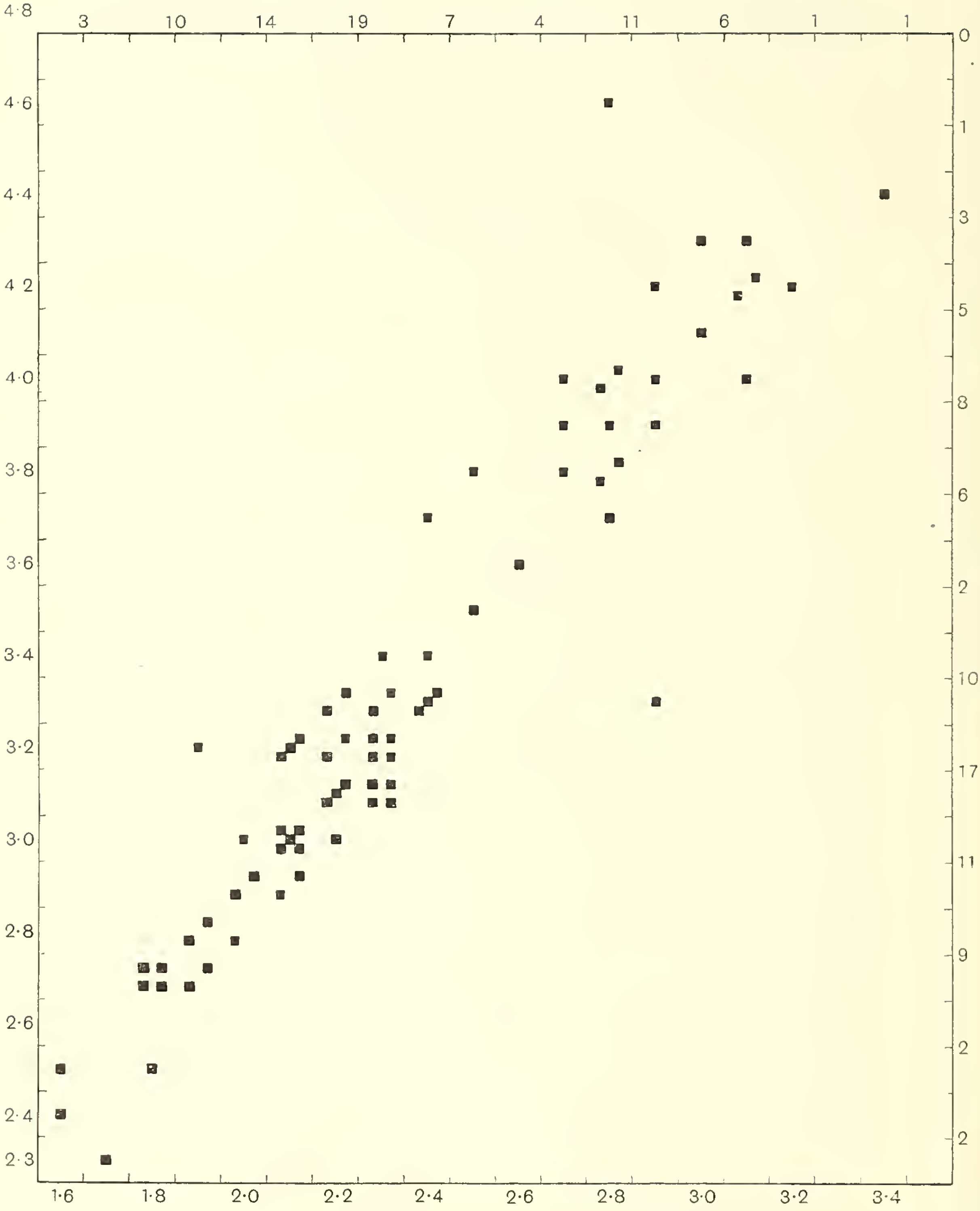

Fig. 1. Correlation diagram, male.

Finally such a mode of expressing the results allows the aberrant variant to be picked out at once. Two individuals only are strikingly abnormal in size, one measuring 3·3 × 2·9 mm. and the other 4·6 × 2·8 mm.; in each case, size only is abnormal, the other characters being similar to those of individuals of similar breadth.

These differences in size may be due either to an intermingling of two or more species or varieties, which are difficult to separate, or to the variability of a single species. In the "male" frequency curve (Fig. 2, ♂) for which, unfortunately, less material was available than was to be desired, it will be noticed that the individuals tend to group themselves about the means, and that such a division is absent in the "female" curve (Fig. 2, ♀). If the division in the former curve were due to the intermingling of two species or varieties, it would probably show also in the latter; as it does not show here, it may be assumed that only one species is present and the explanation of the division in the "male" curve is to be found in the artificial selection mentioned above. The occurrence of a tendency to dimorphism in the male would explain this result equally well, but is not a necessary assumption.

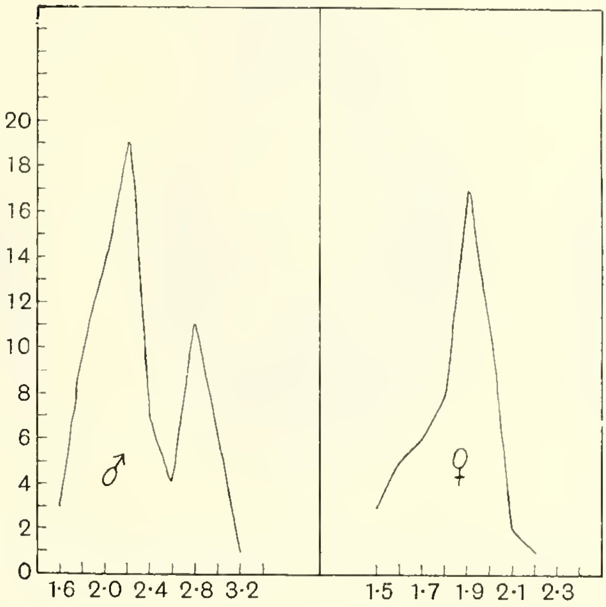

Fig. 2. Frequency curves, male and female.

Pattern of male scutum.

The ornamentation consists typically of five dark-brown islands in a field of white-enamelled appearance, two being immediately behind the cervical grooves, two placed laterally, with inwardly projecting limbs and one in front of the festoons, containing the shallow dorsal furrows which determine its outline (Fig. 3); as such it is remarkably uniform throughout the whole series, what variation there is, never being sufficient to render doubtful the identification of a specimen.

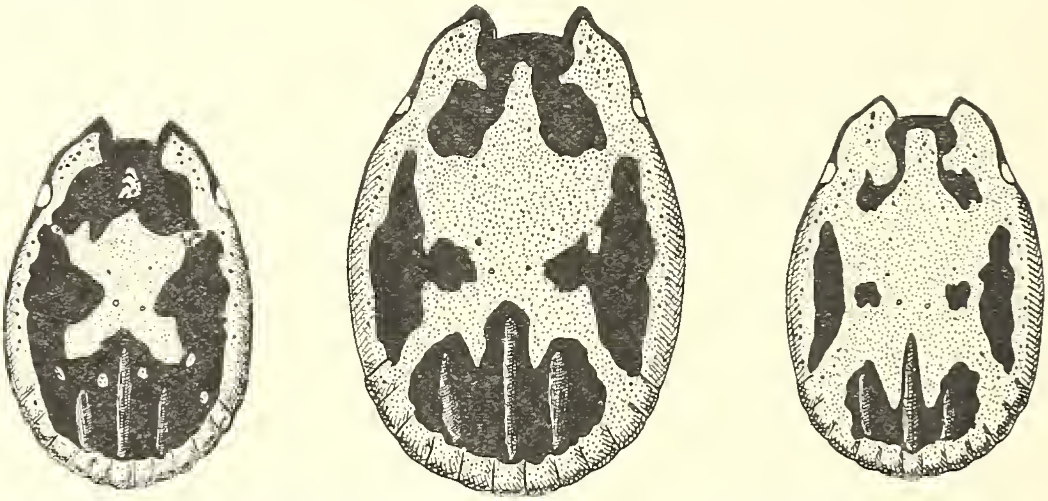

Fig. 3. *Rhipicephalus pulchellus*, males; ornamentation of normal form (central figure) and the two extreme forms, the three scuta being drawn to the same scale. N. C. del.

The departures from the normal take place in two directions. At one extreme, we find that:

1. the anterior islands tend to unite transversely;

2. the lateral islands become triangular, with the apex of the triangle inwards;

3. the posterior island forms an oval mass with its long axis transverse, and in a few cases (Fig. 3) actually unites with the lateral islands, forming a U-shaped marking, the anterior opening of which is partially closed by the anterior island.

At the other extreme:

1. the anterior islands tend to separate and are much smaller than in the normal scutum;

2. the lateral islands become free from their inwardly projecting limbs, which remain in the central field as two small circular patches, making a total of seven islands, instead of the normal number, five;

3. the posterior island tends to break up into three elongated patches, following the dorsal furrows.

It should be noted that the variation of the ornamentation is not dependent on the size of the scutum, the figured specimens all being drawn to the same scale.

Projection of Coxa I.

Normally the anterior projection of coxa I beyond the scutum is easily visible from the dorsal side and it bears a distinct ridge. In the larger well-developed forms this ridge tends to become much stronger and to a slight extent retrograde, whereas in the dwarf males, although the coxal projection is still fairly prominent, the ridge is much reduced and in the smallest individuals (Fig. 4) is hardly apparent at all.

Shape of Basis Capituli.

There is a regular gradation in the size of the basis capituli, with practically no structural variation. The lateral angles are always rounded and distinctly anterior and the cornua strong and blunt. There are generally four small circular depressions arranged in the transverse median line, but the number varies from two to six. A number of hairs passing dorso-ventrally over the lateral angles, in a manner characteristic of *Rhipicephalus*, are present in all specimens.

Palps.

In the typical individual, articles II and III of the palps are notably concave dorsally; this concavity is very pronounced in the large specimens, but in the smallest forms it is absent, and its presence in the type is indicated only by a very indefinite ridge, the dorsal surface of the palp being flat or even slightly convex (Fig. 4).

Cervical Grooves.

These are deep oval pits, equally well defined in all specimens but one, which seems to be imperfectly formed in other respects.

Punctation.

Towards the "dwarf" end of the series the few medium-sized punctations, situated chiefly on the white field, towards the scapulae, become very small, shallow and not readily discernible, those which indicate the obsolete lateral grooves being modified in a similar fashion.

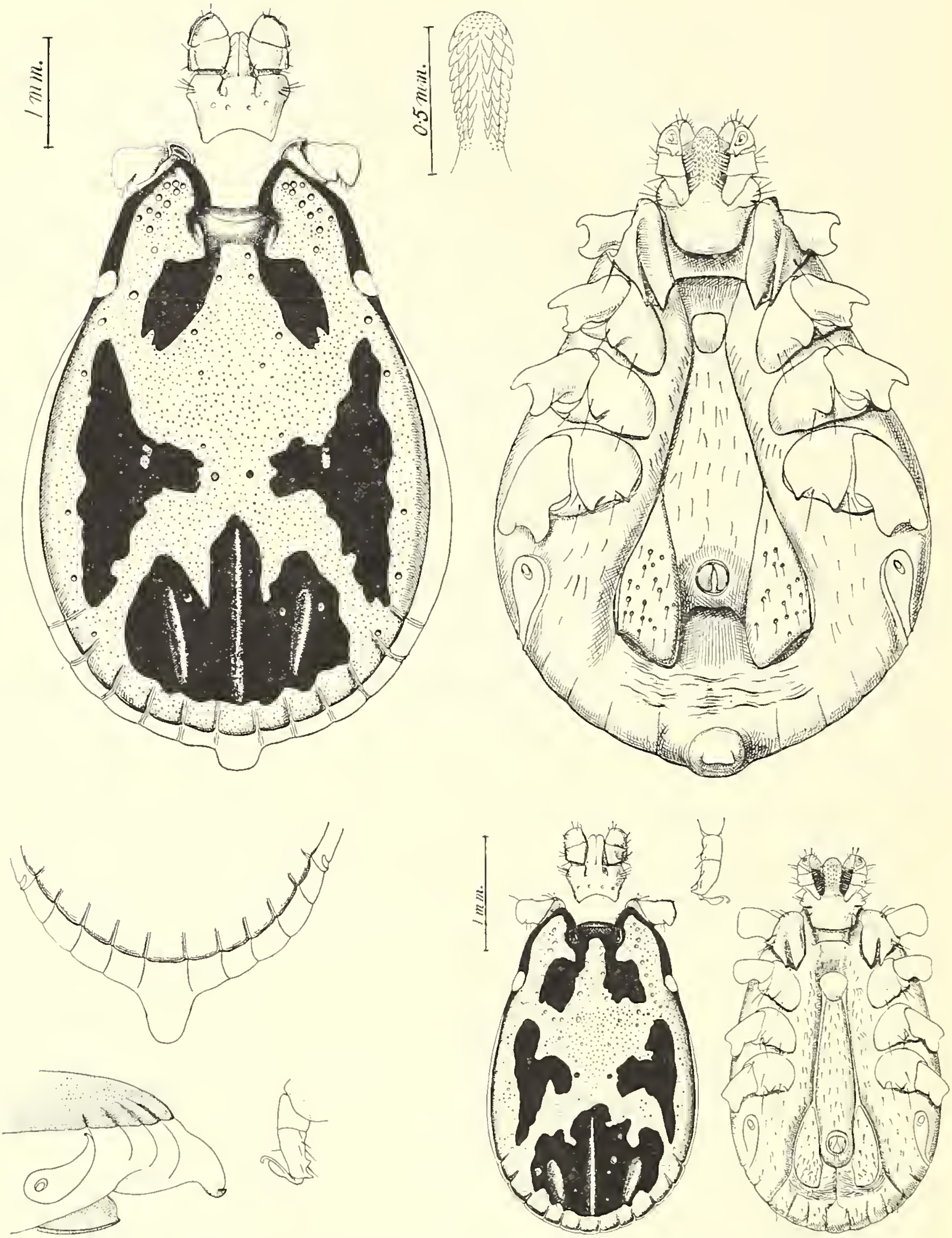

Fig. 4. *Rhipicephalus pulchellus*, extreme types of males, dorsal and ventral aspects; tarsi IV; hypostome of larger male; posterior end of another large well-fed individual, dorsal and lateral aspects, showing orientation of the caudal appendage and the anal plates. N. C. del.

The lateral grooves may be, however, sometimes represented by only three or four punctations, or by a linear series of many deep punctations.

Dorsal Furrows.

Independently of the size of the scutum, there is a considerable variation; in one of the smaller individuals the furrows are deep for the size of the tick and the two lateral furrows equal the median one in length, this extending beyond the anterior margin of the posterior island. In the majority of forms, however, the lateral furrows vary in length from a half to two-thirds that of the median furrow and from scarcely observable oval depressions to narrow elongated but still ill-defined furrows.

Hypostome.

The number of files and approximately the number of denticles on each file is constant throughout the series, but the denticles on the hypostome of the dwarf male are relatively small, not overlapping to the extent observed in the larger forms (Fig. 4), the files being more clearly separate from one another.

Anal Plates, etc.

Here the extreme differences in form will be best appreciated from the figured specimens (Fig. 4), although it may be pointed out that the plate in the larger forms develops an outer angle posteriorly; that in the dwarfs the degree of chitinisation, and hence the visibility, of the plates is but slightly more than that of the general body surface; and finally that the punctation of the plates of the dwarf forms is rather more pronounced than that on the scuta.

There are no accessory plates in this species.

There remain to be considered a few minor points. The legs of the dwarfs have not the pronounced "beady" appearance of those of the typical specimen, but the relative proportions of the false articles of the fourth tarsus are almost constant.

The "foveae" and the minute dark punctations which cover the whole scutum appear to be similarly developed in all specimens. The hairiness of the general body surface is relatively constant, although not obviously so, owing to the fact that the hairs of the larger forms are frequently broken off, leaving stumps visible only under considerable magnification and conveying to the hasty observer the impression of a glabrous surface. The spiracle shows no important modification, but the general chitinisation is less strong in the dwarfs, except for the coxal armature and the auriculae of the basis capituli, and for this reason such organs as the spiracles and the anal plates are not raised above the general surface.

Female Scutum.

The variation in the structural features of the females of *Rhipicephalus pulchellus* is practically negligible, the dwarf specimens being smaller replicas of the larger forms. The ornamentation of the scutum, the cervical and lateral grooves, the punctation, the shape of the basis, the spiracle, and lastly the hairs and depressions of the dorsum, in fact almost all the characters by which a species determination is made, are remarkably constant, except of course in size. The following table gives the extreme and average dimensions of the female scutum:

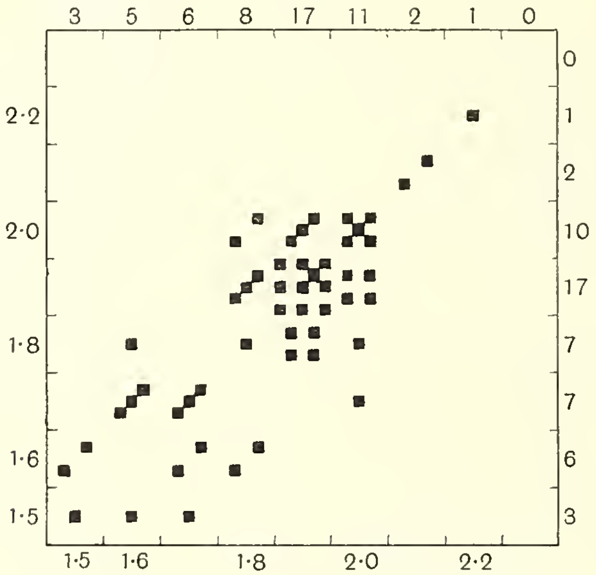

Fig. 5. Correlation diagram, female.

	Length in mm.	Breadth in mm.
Largest specimen	2·2	2·2
Smallest specimen	1·5	1·5
Average specimen	1·9	1·9

In the majority of cases, however, the scutum is either slightly longer than broad or *vice versâ*, as is shown by the spreading on each side of the diagonal in the correlation diagram (Fig. 5). Here also the correlation coefficient is high, being 0·95.

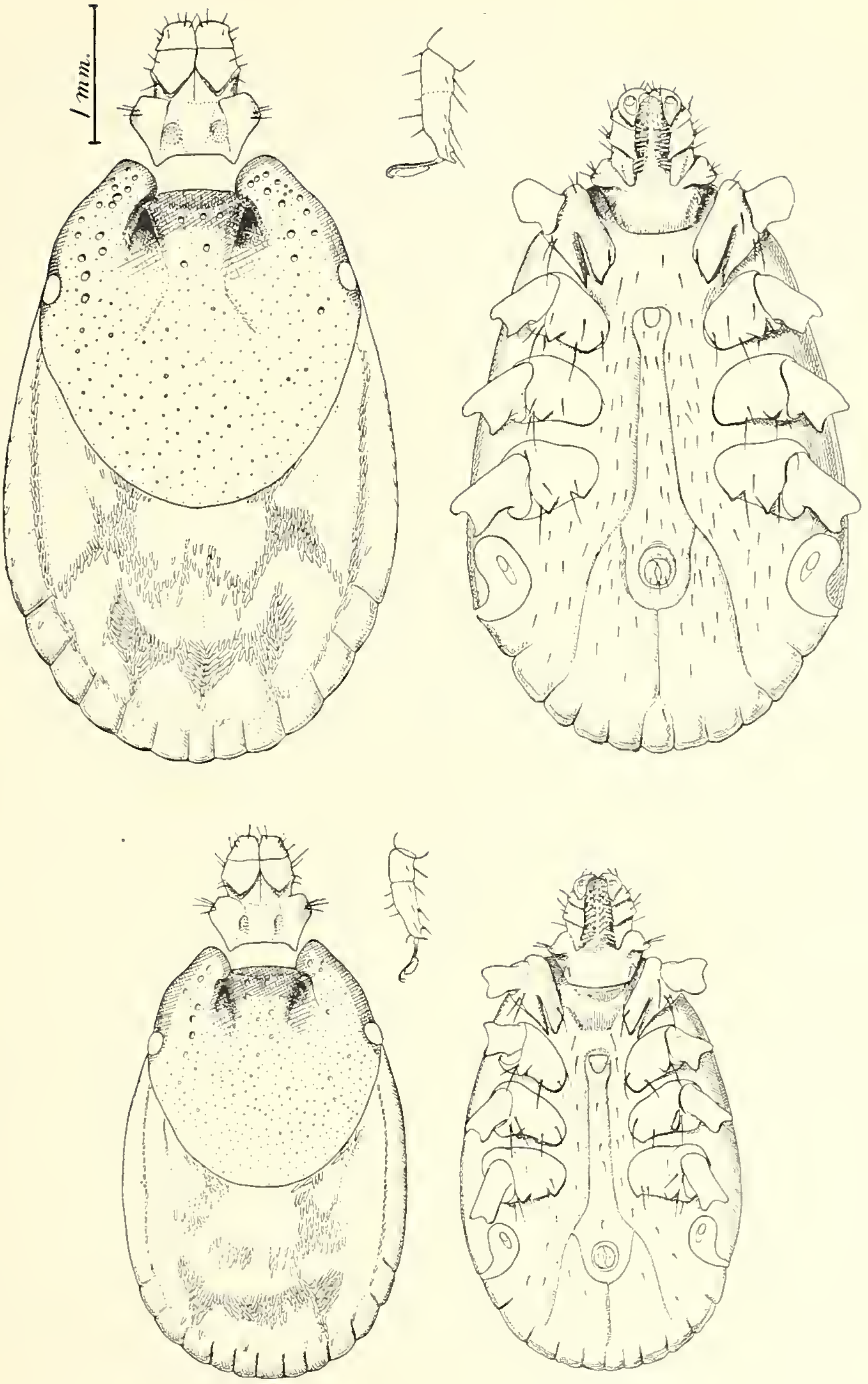

Fig. 6. *Rhipicephalus pulchellus*, extreme types of females, dorsal and ventral aspects; tarsi IV. N. C. del.

Porose Areas.

Independently of the size of the tick, the porose areas may be either round, or oval, with the long axis parallel to the median line. When the areas are round, the interval between them is about equal to their diameter, but when they are oval, the interval is equal, approximately, to twice their breadth (dwarf female, Fig. 6).

Between these two extremes, every stage of gradation may be found.

Lateral Grooves.

The lateral grooves are generally obsolete, but occasionally may be just visible anteriorly.

The question as to what comprises a species is very difficult to answer. It is a problem which all systematists love to attack, but the solution is necessarily influenced by personal bias, species being artificial separations tolerated only on account of their utility.

We have seen that the variability of this species both in size and form is very considerable and it is not possible to do more than indicate the range found within the species.

The value of the various structural features, on which the species of *Rhipicephalus* are based, remains to be considered. In both sexes, we find in the dwarf forms, structural characters differing considerably from those exhibited by the normally developed ticks—for example, the anal plates and the form of the palps in the male, and the porose areas in the female, each of which is a differential character. If *Rhipicephalus pulchellus* had been an inornate species, the dwarf forms would certainly have been considered, even by recent authors, as distinct species. Therefore as in all other biological sections great care must be exercised in future with regard to species formation, at least within the genera of the *Brevirostrata,* due regard being paid to the probability of an apparently new form (differing perhaps from a known species in one or two characters only) being but a variant of a known species. From this point of view an investigation of the range of the variability, at any rate of pathogenic species, would be of considerable value.

Geographical Distribution.

Since 1904, many specimens of *Rhipicephalus pulchellus* have been received at this laboratory, through the courtesy of the Imperial Bureau of Entomology and of many private collectors. It is however a comparatively rare tick, since during a period of nine years only 44 consignments have been received by Prof. Nuttall, the total number of individuals received, being at a liberal estimation, between seven and eight hundred, although on one or two occasions, when the hosts have been very badly infested, as many as three hundred ticks have reached us from the one host.

With three exceptions, *R. pulchellus* has been obtained only from British East Africa and Uganda, in which provinces it is widely spread[1]. In April 1912, D. S. G. Parham collected this species from bullocks in various localities in Zanzibar; Dönitz also received specimens, which were sent to him by Rob. Koch, from cattle in this island; in Nov. 1909, a number of these ticks from a dog were sent by R. E. Drake-Brockman from British Somaliland, and R. I. Pocock (1900) described the species as new under the name *R. marmoreus* from one male collected in May 1895 at Bularli, West Somaliland (no host mentioned)[2].

The tick has probably been spread over the adjacent provinces, from its home in British East Africa, by cattle and dogs, these animals being the usual hosts in Somaliland, Zanzibar, etc.

Hosts.

R. pulchellus is commonly known as the "Zebra Tick" but it is not peculiar to this host, occurring more frequently on other animals. It has also been collected from desert country in B. E. Africa and swept from grass at various localities along the Uganda Railway, B. E. A.

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[1] Localities mentioned by Neumann (1911) and Dönitz (1905), other than those indicated above, are as follows:

Neumann—Zanguebar, Abyssinia, German East Africa.
Dönitz—Pangani, Aruscha, Moschi.

[2] In 1911, through the kindness of Prof. Newstead, we received a number of ticks sent by Capt. R. Markham Carter from Kasauli, Punjab, India, the hosts being cattle and *R. pulchellus* was alleged to be amongst these. In view of the restricted distribution of the species it is very possible that the Indian locality is wrongly given, and until confirmed no reliance may be placed upon it.

The following authentic list gives some indication of the variety of its hosts[1]:

Ungulata	*Equidae*	Various species of *Equus*, including	Horse, Ass, Zebra.
	Rhinocerotidae	*Rhinoceros* sp.	Rhinoceros.
	Suidae	*Phacochoerus aethiopicus*	Wart-hog.
	Bovidae	*Connochaetes albojubatus*	Wildebeeste.
		Bubalis caama	Hartebeeste.
		Cobus ellipsiprymnus	Waterbuck.
		Strepsiceros imberbis	Lesser Kudu.
		Oreas canna	Eland.
		Oryx calotis	Fringe-eared Oryx
		Aepyceros melampus	Impala.
		Bos taurus	Cattle.
Carnivora	*Felidae*	*Felis leo*	Lion.
	Hyaenidae	*Hyaena striata*	Striped Hyaena.
	Canidae	*Canis* sp.	Domesticated and wild dogs.

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[1] Dönitz (1907) cites as a host the bird *Francolinus infuscus* (Phasianidae) and Neumann (1911) similarly, the Gnu (*Connochaetes gnu*); but the latter animal inhabits South Africa only, of which locality no mention is made.

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